

METALLURGIA

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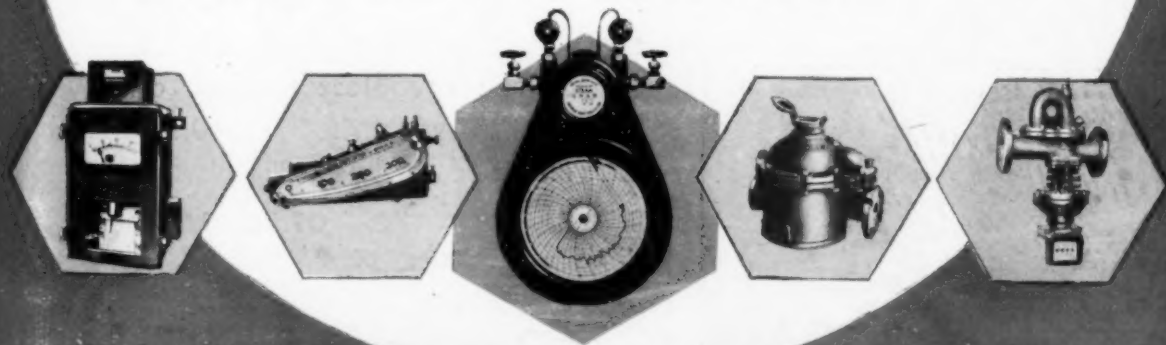
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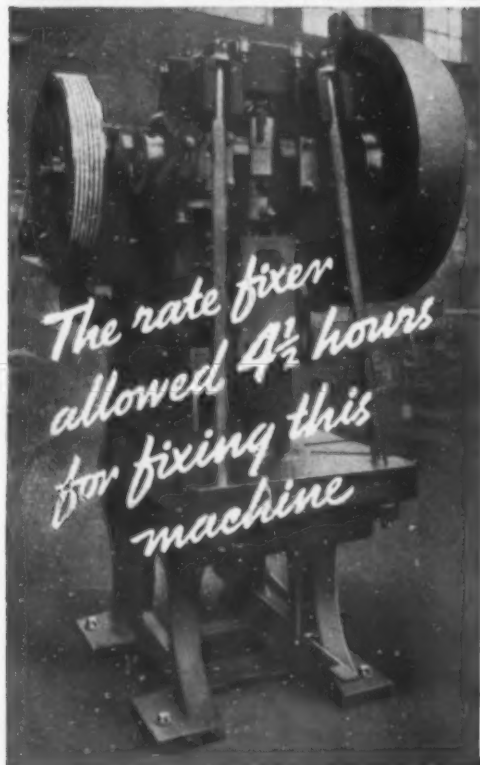
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METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER.)

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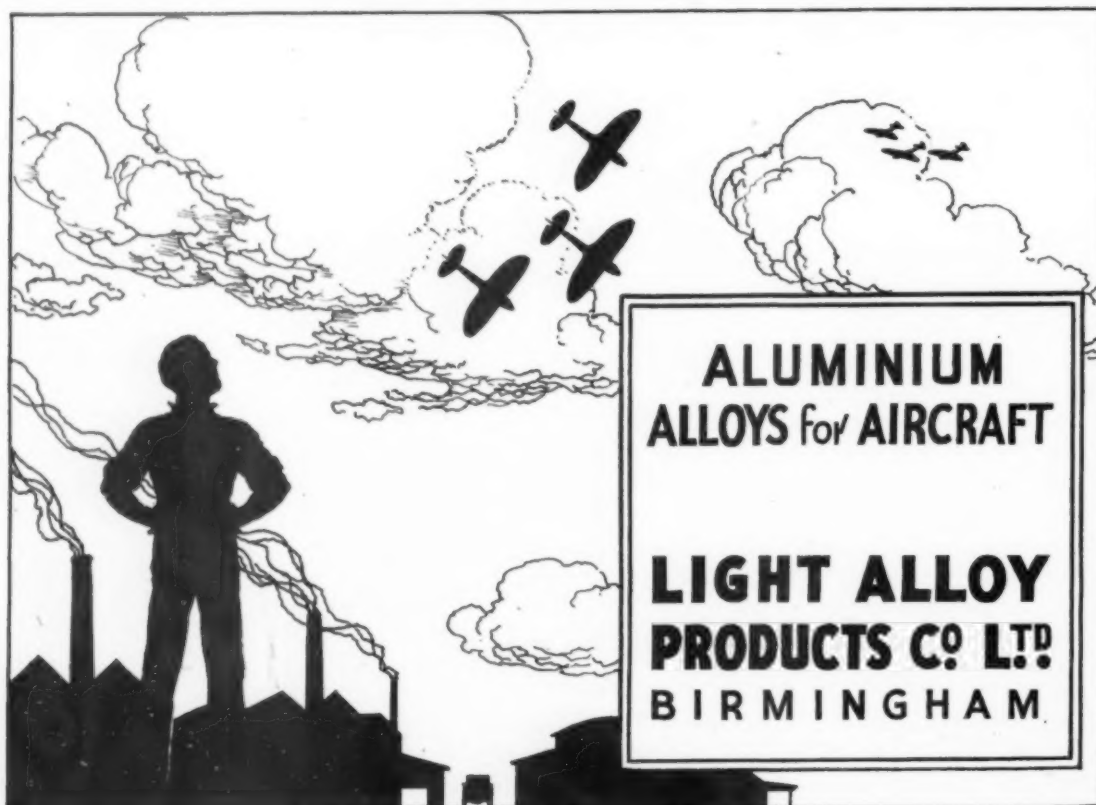
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Cast Iron and the Foundry Industry

By J. E. Hurst, D.Met.

In the field of cast-iron metallurgy great progress has been achieved. Developments also include production technique in melting and melting appliances, sand preparation and handling, moulding and core-making operations, cleaning and fettling castings and, in general, mechanisation of foundry production. Although it is not possible to deal with these developments here, the views expressed by the author indicates some directions in which progress in this field is contributing in the war effort.

THE importance of a material in the war effort is not measured solely by its output expressed in tons, and in spite of the fact that on this basis the output of iron in the form of castings is considerably less than that of other materials in the ferrous group, cast iron plays an indispensable part in the war effort. An absolutely indispensable component of all engines, aircraft, tank, submarine and locomotive is the cast-iron piston ring. The cast-iron cylinder or liner is almost the very heart of our armoured vehicles and locomotives, and the characteristic properties of rigidity and damping capacity play a valuable part in the choice and selection of cast iron as the material of construction in the vastly expanded output of precision machine tools.

The scope of any article on the subject of the developments and progress in the field of cast-iron metallurgy, as in any other metallurgical field of necessity, is very much restricted. It is quite impossible to deal with detailed developments, which those who are in touch in one way or another with the production of castings in grey and malleable cast iron are familiar. These developments concern not only matters relating to production technique but also the

metallurgy of the subject, and when the time allows of their full description the very least that can be prophesied is that our understanding of the characteristics and properties of these alloys will be still more profound.

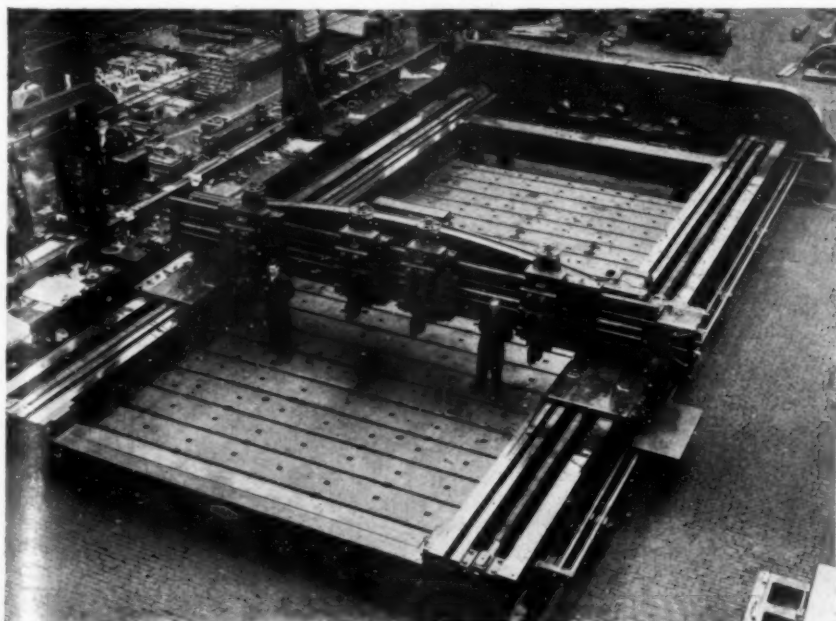
In the whole field of the foundry industry, during the period since the last war, progress and development has taken place at a rapid rate. Developments in melting appliances and technique, in sand preparation and handling, in moulding and core-making operations, in cleaning and fettling castings, and in complete and co-ordinated mechanisation of foundry production have been many during this period. Perhaps the largest single improvement in moulding or casting technique and production is that of the centrifugal casting process, the extensive development of which has taken place during this period. In the more particular field of cast-iron metallurgy this period has been characterised by almost feverish activity and research. The many developments which have resulted and the creation and accumulation of a vast store of new knowledge has become widely known through the activities of the British Cast Iron Research Association established during this period, the Institute of British Foundrymen, and other

scientific and metallurgical associations and establishments, both in this country and abroad. The utilisation of all these developments and the application of this vast store of new knowledge has been the concern of the foundry industry and its personnel during this war. Countless opportunities have arisen in which these developments, both in production methods and metallurgical technique, have displayed themselves to advantage in the prosecution of this war effort.

Soundness in Castings

The most important feature in any casting is its soundness and freedom from internal defects. Such considerations stand in front of any other properties and qualities. Apart from the work of many individual investigators, intensive research into many aspects of these problems has been carried out by both the Cast Iron Subcommittee of the Institute of British Foundrymen and the

Fig. 1.—An armour-plate pit-type planing machine.



British Cast Iron Research Association. As a result of this work new light has been thrown upon the importance of chemical composition, and a fuller understanding obtained of the effects of pouring and cooling conditions. In so far as the chemical composition is concerned the importance of the control of the silicon content has been placed in a new perspective, and the discovery of the important part played by the total carbon and phosphorus contents has enabled methods and rules to be worked out for the adjustment of the balance of chemical composition to obtain conditions ensuring maximum soundness. The relationship of melting temperature, casting temperature, rate of cooling, and the use of chills, the factors which operate in the successful feeding of castings, including gating, moulding, layout and technique, is more thoroughly understood.

The home ores used for the production of foundry irons are essentially phosphoric, and the many grades of pig iron which were available, of medium and low-phosphorous contents, relied very much on the use of imported ores in their production. The necessity for making the fullest possible use of home resources of phosphoric ores and phosphoric pig irons is a matter of first-rate importance to the foundry industry. In his approach to the problems associated with the maximum use of phosphoric irons, the foundryman's first concern is the question of soundness, and it is here that the knowledge gained has proved invaluable. It is possible for the foundryman and metallurgist to plan

those cast irons developed specially for their high-strength properties, included those made from mixtures containing a high percentage of steel or refined iron; cast irons made in special furnaces, air furnaces, rotary and electric furnaces, alloy cast irons in which the elements nickel, chromium, molybdenum and copper are used principally; heat-treated cast irons and cast irons of Ni-Tensyl and Meehanite types.

It is important to emphasise that in the commercial production of the high duty cast irons the actual process of manufacture is equal in importance to the chemical composition, perhaps even more so in the case of the highest qualities. To comply with the maximum requirements of B.S.I. 786, outlined in grades 3 and 4, the components of the metal mixture, the method of melting and the manner in which the alloy additions are made, in those instances where alloys are used, are all of importance in obtaining the desired results. As an example, it is possible to refer to the discovery of the effect of late additions of alloying elements. It has been discovered that the addition of certain elements such as silicon and nickel, which have a graphitising effect, has a very much more pronounced effect on the strength properties when added as a ladle addition to molten white iron than when included in the pig iron or scrap in the charge. This method has been referred to as the inoculation method, and is the basis of such processes as Ni-Tensyl, where nickel and silicon are added as late additions to molten low-carbon irons made from high steel or white refined iron charges.

TABLE I.
MECHANICAL STRENGTH REQUIREMENTS OF B.S.I. 321 AND 786.
ULTIMATE TENSILE STRENGTH U.T.S. AND TRANSVERSE STRENGTH T.R.S. TONS/SQ. IN.

Test Bar—Diameter Inches.	0.6			0.875			1.2			1.6			2.1		
	Not more than 2 in.			Over 2 in. and not more than 4 in.			Over 4 in. and not more than 14 in.			Over 14 in. and not more than 24 in.			Over 24 in.		
Section of Casting Represented in Inches.	U.T.S.	T.R.S.	D.E.F.	U.T.S.	T.R.S.	D.E.F.	U.T.S.	T.R.S.	D.E.F.	U.T.S.	T.R.S.	D.E.F.	U.T.S.	T.R.S.	D.E.F.
B.S.I. 321—Grade C	10.0	19.9	0.06	10.0	19.6	0.09	9.0	18.9	0.13	9.0	18.3	0.10	9.0	17.7	0.14
B.S.I. 321—Grade A	12.5	25.1	0.07	12.0	24.1	0.10	11.0	23.1	0.15	10.5	21.4	0.12	10.0	19.6	0.15
B.S.I. 786—Grade 1	14.0	27.0	0.07	13.0	25.9	0.11	11.0	25.0	0.16	13.0	24.0	0.13	12.5	23.6	0.17
B.S.I. 786—Grade 2	19.0	39.0	0.08	18.0	28.9	0.12	17.0	28.0	0.17	16.0	27.0	0.14	15.0	26.1	0.19
B.S.I. 786—Grade 3	23.0	34.0	0.09	22.0	33.0	0.13	20.0	31.0	0.18	19.0	30.0	0.16	18.0	29.1	0.21
B.S.I. 786—Grade 4	26.0	41.0	0.10	25.0	39.0	0.14	23.0	37.0	0.23	22.0	35.0	0.18	21.0	33.0	0.24

U.T.S. = Ultimate tensile strength.

T.R.S. = Transverse rupture stress.

D.E.F. = Deflection, inches.

the chemical composition, melting and pouring conditions, moulding layout, gating and feeding arrangements with a greater degree of precision, and in this respect he is much better placed for dealing with the production of sound castings than were his predecessors in the last war.

The second report of the Research Committee on High Duty Cast Irons for General Engineering Purposes of the Institution of Mechanical Engineers, which appeared in the middle of 1941 was wholly concerned with engineering phosphoric grey cast iron free from alloying elements. This report is of special importance in any considerations relating to the use of indigenous phosphoric foundry irons.

High Duty Cast Iron

One measure of the extent of the progress made in the field of the metallurgy of cast iron is to be found in the examination of the existing British Standard Specifications for cast iron and high duty cast-iron castings. The leading requirements of these are summarised in tabular form in Table I. B.S.I. Specification 321, which was first drawn up in 1928, has been extended by the B.S.I. Specification 786 for high duty castings, first issued in 1938. This latter covered three grades, the highest grade calling for a minimum tensile strength of from 18 to 22 tons per square inch, according to the size of casting and test-bar. B.S.I. 786 has since been extended by the addition of a fourth grade in which a minimum strength of from 21 to 26 tons per square inch is demanded. In the first report of the High Duty Cast Iron Committee of the Institution of Mechanical Engineers, dated December, 1938, a list of high duty cast irons in general production was compiled. This list, which covered

In the general description of high duty cast irons, it is usual to include other cast irons developed for their special properties, such as resistance to wear, electrical properties, corrosion and heat-resisting properties with or without high strength. These include the martensitic cast irons, the heat-treated and nitrogen-hardened cast irons, the rich alloy cast irons of the austenitic type No-Mag, Ni-Resist and Nicrosilal, the acid-resisting high-silicon irons and the heat-resisting cast irons of the Silal type.

The supreme importance of the economical use of all raw materials under present-day conditions makes it imperative that the whole range of high-duty cast irons shall be used intelligently and efficiently. To secure this a widespread knowledge and comprehension of the properties and possibilities of these cast irons is essential amongst foundrymen, engineers and designers, and with the object of assisting in this the publication "Data on Cast Iron" has been issued under the auspices of the Controllers of Iron Castings of the Iron and Steel Control, by the British Standards Institution,¹ and a special report on the austenitic and martensitic cast irons has been issued by the High Duty Cast Irons Research Committee of the Institution of Mechanical Engineers.

Acicular Cast Irons

The high strength and characteristic structure observed in molybdenum alloy cast irons made under certain conditions² has been investigated more particularly in America³ and is now more fully understood. The term

¹ B.S.I., 991, 1941.

² Hurst, F.T.J., 1938; McPherran, A.F.A., 1937.

³ Flinn and Reese, A.F.A., 1941.

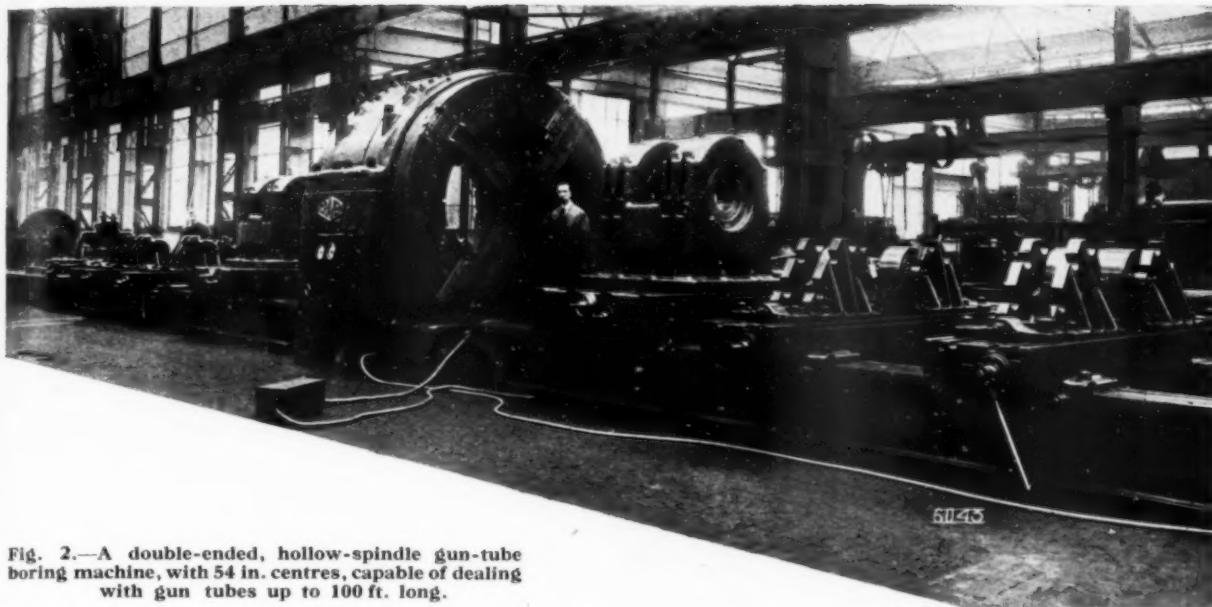


Fig. 2.—A double-ended, hollow-spindle gun-tube boring machine, with 54 in. centres, capable of dealing with gun tubes up to 100 ft. long.

"Acicular Cast Irons" is now used to refer to this special group of high duty cast irons possessing this characteristic acicular structure, and such irons possess mechanical properties superior to irons of normal structure, particularly after subjection to a low-temperature treatment at temperatures of from 300° to 500° C. Flinn and his co-workers⁴ investigated the isothermal transformation of austenite in nickel-molybdenum cast iron in order to determine the mechanism of the formation of the acicular structures found in these high-strength cast irons. These structures were found to consist of a series of transformation products of a complex character differing from normal pearlite and resembling in appearance martensite, hence the term "acicular structure." The increase in strength which occurs on tempering nickel acicular molybdenum cast irons in the range of 260° to 370° C is attributed by them to the relief of stresses, and to the transformations occurring within the residual austenite-martensite of the matrix. The continued development of these acicular irons will be watched with close interest by foundrymen, and already in certain directions they have been found to give excellent results under high duty conditions.

Research Activities

In spite of the many difficulties the activities of various technical committees and research associations are continuing. The Institute of British Foundrymen and its various technical committees have continued their work with unabated vigour, and the British Cast Iron Research

⁴ Flinn and others, A.S.M., 1941.

Association has likewise been very active. In America the investigations undertaken by individual research workers and the American Foundrymen's Association have been admirably summarised in the paper by Dr. A. B. Everest, which appeared in the *Foundry Trade Journal* in the latter months of 1941.

The illustrations show some special machine tools involving a number of interesting iron castings, the production of which demanded a special technique and craftsmanship of a high order. The total weight of the machine shown in Fig. 1 is 220 tons, and some of the important castings include the cross-slide, cast in one piece and weighing 18 tons; the right- and left-hand beds, cast in four pieces and weighing 70 tons; and the base plate, cast in four pieces and weighing 90 tons. The total length of the lathe, of which only a part is shown in Fig. 2, is 260 ft., and the total weight 230 tons. The beds were cast in 10 pieces and weighed 100 tons; the main casting for the headstock weighed 23 tons, while the cast-iron spindle weighed 21 tons. The spindle revolves on brass pads, of generous area, located in the headstock. The composition of this spindle is as follows:—

Total Carbon.	Silicon.	Phosphorus.	Manganese.	Sulphur.
3.10%	0.85%	0.40%	0.60%	0.12%

All the main castings in both machines have their sliding faces densened. The metal is of the medium-phosphorus, low-silicon quality.

[We are indebted to Mr. E. Longden, Messrs. Craven Bros., Ltd., for his courtesy in supplying photographs, which are reproduced in these illustrations.—EDITOR.]

D.T.D. 126A.—A Useful Carbon-Manganese Steel

By Bernard Thomas, F.Inst.P., F.Inst.F.

THE short supply of alloy elements, bringing in its train the restricted release of alloy steels, has resulted in the greater use of alternatives of lower or non-alloy composition. Although in the majority of cases such alternatives were used prior to restrictions, it was to nothing like the extent as now obtains, and it was inevitable that such greater usage would result in a wider knowledge of their properties. In these remarks it is proposed to discuss the properties of one of the "kindest" of the alternatives being employed for drop-stampings and forgings with the suggested view to its still wider application. The steel in question is described as D.T.D. 126A.

In qualification of the term "kind," it should be explained that certain steels may be manipulated in the heated stages of drop-forging, and subsequently in heat-treating, with a much greater freedom than others, and this property, coupled with the less frequent occurrence of physical troubles, leads users to discriminate such types by the adjective in question for the obvious reason. D.T.D. 126A most certainly is worthy of such description in the experience of the writer after the handling of some thousands of drop-forgings in such composition during the last twelve months.

For the edification of those readers who are not wholly

familiar with steel specifications, the chemical composition and mechanical property requirements of the steel are given in Table I.

TABLE I.
SPECIFICATION D.T.D. 126A.—CHEMICAL COMPOSITION AND MECHANICAL PROPERTIES.

Chemical Composition.			
Carbon	0.30 max.	Sulphur	0.05% max.
Silicon	0.30% "	Phosphorus	0.05% "
Manganese	1.75% "	Nickel (if present)	0.20% "
Mechanical Properties:			
Ultimate stress	40-55 tons per sq. in.		
Elongation	20% minimum.		
Brinell hardness	187-248.		
Izod value	35 ft.-lb. minimum.		

For those more familiar with the 1942 En series of specifications, the foregoing composition corresponds most nearly with BS.En. 14, the major difference being that carbon, silicon and manganese have a fixed minimum limit in the latter specification, and slightly greater amounts of nickel, sulphur and phosphorus are permissible.

Described as a carbon-manganese steel suitable for tensile strengths of 40-45 tons, the material welds and forges quite readily. The amount of manganese usually present is invariably over 1.0%, and this ensures that the whole of the sulphur is taken care of as manganese sulphide, not only to theoretical amount necessary for the molecular formation of the compound, but to the much greater extent as dictated by usual practical requirements. This prevents the risk of "red-shortness" which naturally is reflected in the enhanced welding and forging properties.

As regards heat-treatment, it is laid down in the D.T.D. specification that the quenching temperature should not exceed 860° C., while the En series advised 840°-880° C. for quenching in oil or water. With most average analyses 870° C. appears to be the most suitable temperature for oil quenching, with ruling thicknesses up to, roughly, 2½ in. Temperatures less than this give rise to "patchy" results, indicative of working too close to the safe figure. Where, of course, a ruling thickness of ½ in. to ¾ in. obtains, this quite often will be all right from, say, 850° C., but to adopt this lower figure as standard involves some risk, unless the treater is sufficiently familiar with his compositions to adjust his temperatures according to fluctuation of carbon and/or manganese.

Critics may say that it is splitting hairs to bother to this extent over a quenching temperature, but the writer puts forward the argument that in a given plant handling, say 50 tons per day of quenched work, the difference in heat, dissipation required of the already sadly overtaxed oil-quenching facilities by a difference of 20° C., with the specific heat of steel taken as 0.16, is in itself formidable, quite apart from the waste of fuel to maintain a furnace at 870° C. if 850° C. will suffice.

Beyond 2½ in. ruling thickness up to 4 in., it is more often necessary to resort to water quenching. This, however, necessitates some reduction in quenching temperature to avoid quench cracks, and while no hard-and-fast rule may be laid down without knowledge of forging shape, somewhere in the region of 840°-850° C. is most likely to be successful.

Tempering depends largely on degree of hardness obtained by the initial quench, and while between 550° C. and 660° C. is advocated by the specification, 550°-580° C. is

TABLE II.
TYPICAL PHYSICAL PROPERTIES YIELDED BY STEEL TO SPECIFICATION D.T.D. 126A.
ALL TEST PIECES MEASURED 1½ IN.—1½ IN. DIAM.

Reference No.	Batch No.	Cast No.	Ultimate Stress, Tons.	Elongation, %	Brinell, 3,000 kg./10 mm.	Izod Values, Ft.-lb.
1	1875	35804	41.8	28.0	196	99-99-93
2	2334	"	42.4	28.5	207	88-83-80
3	3430	"	43.5	25.0	207	85-82-76
4	2335	31111	42.4	27.5	212	87-77-90
5	2405	"	45.2	29.5	207	95-96-99
6	3148	K.9541	43.0	28.0	197	82-80-78
7	3377	"	41.8	31.0	187	95-92-99
8	1708	29979	45.1	22.5	229	74-73-76
9	1733	74286	46.5	26	241	80-87-82
10	2309	E.886	42.8	29.0	207	119, 107, 114

usually that employed to yield mechanical test requirements. A typical range of physical properties, yielded by test-pieces covering recent batches of forgings handled, is given in Table II.

Particular attention is drawn to the extraordinarily high Izod impact figures in comparison with the specified minimum requirement of 35 ft.-lb. No. 10 steel is very noticeable in this respect, where one figure reaches 114 ft.-lb. It may be gathered from such figures how tough and fibrous a fracture is offered after treatment.

The story would be incomplete without mention of chemical composition, and in Table III are given the cast analyses of the six casts involved by the ten sets of physical figures. It is appreciated that ideally the actual analysis of the test-piece itself would be preferable to the cast analyses but, unfortunately, time and reduced staffs do not permit of such refinements and after all the cast analysis is submitted to the heat-treater as being of value as a guide for treatment, and as such is taken at its face value accordingly in the work under review.

TABLE III.
CHEMICAL COMPOSITIONS OF D.T.D. 126A STEEL CASTS COVERED BY TABLE II.

Reference Nos.	Cast No.	Carbon, %	Silicon, %	Manganese, %	Sulphur, %	Phosphorus, %	Chromium, %	Nickel, %
1, 2 & 3	35804	0.27	0.25	1.65	0.033	0.019	—	—
4 & 5	31111	0.27	0.27	1.29	0.021	0.024	—	0.20
6 & 7	K.9541	0.28	0.30	1.52	0.043	0.027	0.03	0.09
8	29979	0.28	0.30	1.70	0.031	0.043	0.10	0.19
9	74286	0.25	0.29	1.77	0.013	0.016	0.06	0.12
10	E.886	0.24	0.18	1.44	0.029	0.030	—	0.05

N.B.—The elements carbon and manganese are shown in bolder type for ease of assimilation.

It may be of interest to point out that, based on "hardening values," obtained by the formula described in a previous article,* where after 10 times the sulphur content is deducted from the manganese and one-third of the latter element remaining is added to the carbon to produce an arbitrary figure for assessment of hardening value, the steel having the highest value so obtained of 0.80 in.—i.e., Ref. No. 9, Cast No. 74286, also yields the highest tensile figure of the group at 46.5 tons.

While all the ultimate stress values as shown in Table II fall between 40 and 50 tons, only three exceed 45 tons. It is, however, only a question of reducing tempering temperature to increase the others to higher tensiles, which brings the physical properties into very favourable comparison as an alternative for the 3% nickel oil-hardening steel to BSS. 5005/401 or its En 21 equivalent. In Table IV is set out the physical requirements of BSS. 5005/401 steel.

TABLE IV.
MECHANICAL PROPERTIES OF STEEL TO SPECIFICATION B.S.S. 5005/401.

Ultimate stress	45 tons per sq. in. minimum.
Elongation	22% minimum.
Brinell hardness	192 minimum.
Izod value	40 ft.-lb. minimum.

Comparing the typical physical results obtained from D.T.D. 126A, as set forth in Table II, it will be appreciated that the ultimate stress requirements of BSS. 5005/401 may be obtained with reasonable ease by adjustment of tempering temperature without undue risk of brittleness. Elongation percentage is well satisfied in every instance, with much latitude in most cases.

In nine out of the ten tests the Brinell hardness exceeds the minimum figure, while the one which fails at 187, as against 192, is sufficiently near to be accepted as satisfactory.

In small sections, where the degree of hardness obtainable on quenching is greater, it is even possible to obtain the requirements of a 3½% nickel steel such as BSS. 5005/402 or En. 22, which call for a tensile range of 55/65 tons, and it is for these reasons that this very commendable carbon-manganese steel is brought to the notice of readers.

* METALLURGIA, October, 1942, p. 199.

METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

1942—1943

THE year 1942 proved to be a very critical year for the United Nations, and historians may ultimately regard it as the turning point in the crusade against evil. At the beginning of that year the United States had just previously been forced into the war by the unprovoked attack on Pearl Harbour by the Japanese, and while the United States were just beginning to understand the magnitude of the task forced upon her the Japanese set about giving effect to their desire to dominate the Far East. Their efforts achieved success beyond expectations, and with the fall of Singapore, on February 15, the result of the conflict was anything but bright for the British Commonwealth. The immediate results of the long run of Japanese successes were serious. Allied possessions and prestige in the Pacific, upon which some aspects of the war effort largely depended, collapsed like a house built on sand. Thus, early in that year the pattern of the war had been radically altered by the launching of the Japanese blitzkrieg, the effect of which brought a united America into the war, and there is evidence to-day that this treacherous act of the Japanese is proving a boomerang to the Axis nations.

During the early months of 1942 events in the Pacific almost completely overshadowed what was happening elsewhere. There were no bright intervals to counteract the losses in the Pacific, and until the late summer the tide continued to flow favourable to the Axis forces. The Ukraine and the Don Basin were overrun. Rommel drove our forces from Libya, to be halted only at the very gates of Alexandria. Meanwhile, with the strain on our sea communications enormously increased, the U-boats took greater toll of our shipping.

Later in the year, however, a very substantial change was effected. The Japanese blitzkrieg was halted at a point short of irrevocable disaster, and there are indications to-day that Japan has shot her bolt, though her subsequent overthrow may take a long time; eventually she will be completely at the mercy of the Allies. Russia again showed how seriously Hitler had miscalculated her resource; and her capacity to fight back. The Nazi hopes of a major victory perished in the ruins of Stalingrad, and just six weeks before the end of the year the Russian forces launched offensives all along their front, and with gathering momentum there are indications that in addition to the severe losses already suffered by the enemy, further losses may ultimately be catastrophic. The position in Africa changed completely, bringing about progress comparable with that achieved by Russia. The Nazi victory at El Alamein was timed to coincide with the landing of Allied forces in French North Africa. Now Cyrenaica is in our hands and Tripoli is likely to fall; Rommel is retiring on Tunis, and soon the whole of North Africa will be under Allied control, when the stage will be set for the opening of a second front in Europe. Gradually, throughout the year, the Allied air forces have increased, and everywhere have the measure of the Luftwaffe. On the other hand, our shipping losses are still appalling high, and remain our biggest source of anxiety.

Behind the progress achieved on the many fronts during the course of the year, which has substantially encouraged a feeling of hope in a speedy victory, there has been steady but persistent progress on the production front. Guns, tanks, planes and ships have been increasingly necessary, and the vast amount of work accomplished during the year is sufficient evidence that the determination displayed by the various fighting forces is shared by the vast majority in industry, who are meeting and overcoming numerous difficulties. From opinions on work done by industry, expressed by representative authorities, it is perhaps permissible to cite one. Thus, Mr. W. Edgar Hale, J.P., chairman and managing director of Hale and Hale (Tipton), Ltd., speaking at the recent annual general meeting of the company stated: "Having excellent opportunities of observing what is being done all over the country, I am tremendously impressed with the phenomenal results which have so far been achieved. . . . One hears a lot about bustle elsewhere, but there are very few instances of real bustle that compare in a superior way to what has been done in Great Britain." Production for war purposes has reached higher and higher levels, and in America, Britain, Canada, Australia and South Africa and production will continue to rise and far exceed that of Axis countries.

Some optimistic people have expressed the opinion that 1943 may prove to be the year of victory, but there is no evidence for such a view. We have not yet embarked upon the problem of subjugating Germany. When North Africa is cleared of the enemy the real offensive phase of the war, the attack on Germany, will begin, and it has taken us over three years to prepare for this major struggle. Certainly there will be no victory until Germany is beaten in the field; it is very unwise, therefore, to predict with so much optimism, because the tasks ahead will need all our determination to win through successfully. Despite the great losses the Russians have inflicted on Germany Hitler has still a powerful and well-equipped army, and it can be taken for granted that nothing will be neglected to make his defences secure.

But, by comparison with the beginning of 1942, the outlook for 1943 begins very bright indeed, and though the Allied forces must expect the fight to be hard, and must expect to suffer grievous casualties, by maintaining that same determination which has characterised their exploits in the past, the growing power of their armour will greatly augment their attack until, ultimately, the war is carried into the very heart of the Reich. In giving effect to this, what must be the attitude of those of us not privileged to take part in the actual fighting? It has been said that those in workshops, producing the vital munitions of war, are as much in the battle as the men at the various battle fronts. From some aspects this is probably true, but they have greater liberty of action, and sometimes this is exercised with a complete disregard for the success of the

war effort. Let our attitude be one of absolute determination that no contribution, which any of us can make to the war effort, shall be lacking through any default of ours. To hasten a successful decision, let this year be one of unsparing effort; a year in which idleness, waste and extravagance are recognised as deadly foes; a

The fact that goods made of raw materials in short supply owing to war conditions are advertised in "Metallurgia" should not be taken as an indication that they are necessarily available for export.

year in which we agree to forget personal inconveniences and petty grievances, in the common cause. In short, in word and deed give the Forces all possible support and we may look forward to the launching of an Allied assault upon the Axis which will gain, day by day, in scope and momentum until ultimately it reaches Germany.

There is one other aspect which should not be lost sight of, and which is the concern of those of us not in the fighting line—we must prepare unremittingly for the great tasks to be tackled when the war is over. And we should constantly bear in mind the greater purpose for which the Allied Nations are fighting—world peace based on the recognition of the rights of all free peoples.

New Year's Honours List

AMONG the many who have been honoured for services rendered mention may be made of Alexander Dunbar, Controller-General, Ministry of Aircraft Production, who has been made a Knight Bachelor, as also has George Horatio Nelson, chairman and managing director of English Electric Co., Ltd., and W. Murray Morrison, M.Inst.C.E., M.Inst.E.E., F.Inst.Metals.

Mr. Morrison, who was the Institute of Metals 1942 medallist, can be regarded as the father of the aluminium industry in this country, having been associated with the British Aluminium Co., Ltd., from its inception and responsible for the development here of the electrolytic process invented simultaneously by Hall, in America, and Héroult, in France, in 1887. In 1910 he was appointed general manager of the company and joined the board in 1927. Three years later he became managing director and in 1934 deputy chairman, which two positions he holds to-day.

Col. Sir W. Charles Wright, Bt., K.B.E., C.B., who is a past-president of the Iron and Steel Institute, and was for some time Controller of the Iron and Steel section of the Ministry of Supply, receives the G.B.E.

Mr. Sydney J. Johnstone, B.Sc.(Lond.), F.I.C., who receives the O.B.E., is Principal of the Mineral Resources Department of the Imperial Institute, where he has been associated with the investigations and development of Empire mineral resources since 1903. At the outbreak of war he took charge of the Commodities Intelligence Section of the Ministry of Economic Warfare. Mr. Johnstone is a general member of Council of the Institute of Chemistry and vice-chairman of its London Section. He is also a member of the London Section Committee of the Society of Chemical Industry.

Hardness of Tin-Base Alloys

METHODS of obtaining new and stronger tin-base alloys suitable for use as bearing metals is part of the programme of research conducted by the Tin Research Institute.

The effect on hardness, produced by quenching from the highest practicable temperature, followed by prolonged tempering at 100° and 140° C., has been examined for 80 tin-base alloys containing 4 to 14% antimony and 0 to 10% cadmium. The results of the hardness tests are recorded in a paper by W. T. Pell-Walpole, B.Sc., Ph.D., an abstract of which was published in our November issue.

It is shown that these alloys can be hardened by heat-treatment, and maintain a useful degree of improvement for at least 1,000 hours at 100° to 140° C. The best alloys in this respect are those in the range antimony, 9 to 10% cadmium 1 to 1½%, balance tin. The degree of improvement is indicated by Vickers' diamond pyramid hardness tests. Values of 33 to 34 are obtained, compared with values of 26 to 30 in the normal non-heat-treated condition.

Reprints of this paper may be obtained free of charge from the Tin Research Institute, Fraser Road, Greenford, Middlesex.

Note on Substitution of Acetylene by Propane or Coal Gas

It is necessary to economise in the usage of calcium carbide for both shipping reasons and on account of new war demands. Supplies will be maintained to essential consumers who are unable to effect any substitution. This maintenance, however, depends in some measure upon reducing consumption in other directions.

In metal-cutting and non-ferrous welding, the actual welding medium may be one of several gases, of which acetylene is the most commonly used. Propane, or boosted coal-gas, can, and should, be used in place of acetylene wherever this is technically possible, thus saving many thousands of tons of imported carbide. On the ferrous-welding side, when new plant is installed, this should be for electric welding in preference to gas plant, while much light-gauge welding work now done by acetylene could frequently be done as well by arc.

Propane is a by-product of petroleum refining. Sufficient supplies are available to meet all the purposes for which it could be substituted. These purposes cover all those for which acetylene is normally used, except the welding of iron and steel. One 56-lb. cylinder of propane can do the same amount of work as three 200 cub. ft. cylinders of dissolved acetylene. Propane therefore economises both steel and man-hours in the manufacture of cylinders. The cost and efficiency of both propane and coal-gas compare favourably with that of acetylene.

There is always a prejudice against making changes, and there appear to be some unfounded objections in the minds of those who have not tried this comparatively new cutting medium. It is, for instance, suggested that propane takes longer to heat the metal up to the required temperature. This is a fallacy, although the flame does require a more critical mixture of gas and oxygen, and the limits of adjustment are finer than when dissolved acetylene and oxygen are used. This flame adjustment is easily mastered by anyone who can use a torch properly, and once the flame is correctly set it will not blow back as does the acetylene flame, and a narrow clean cut is effected. On this score, then, propane is a better cutting medium than acetylene.

Coal-gas can be used for cutting and for certain non-ferrous welding. The amount required, even if substitution were carried to the limit, is very small compared with the demands for other purposes. The gas may be used direct from the mains for machine cutting, or with its pressure boosted for hand-cutting. Better results may be obtained if the coal-gas is enriched with some other gas, such as propane, methane, ether, or acetylene. As coal-gas is piped round the works its use also economises cylinders.

Zinc Alloy Die-Casters' Association

AN association, known as the Zinc Alloy Die-Casters' Association, and comprising most of the leading producers of zinc alloy die castings, in this country, has recently been formed. One of the principal objects of the Association is to enable greater co-operation between the industry and Government departments. By means of this Association the industry can put forward its views as a collective body, and Government departments can put their views to the industry as a whole.

Although formed principally to fulfil this object, it is proposed that the Association will continue to function during peace-time, and much of its work is, of course, applicable both in war and in peace. Among its other aims is the improvement of the technique of zinc alloy die-casting, and the promotion of a fuller appreciation of the properties and applications of the castings.

A fully representative Council has been formed and the Association is operating from the same office as the Zinc Development Association, which is at Lincoln House, Turl Street, Oxford.

Rationalisation in Iron Foundries

By F. L. Meyenberg, M.I.Mech.E.

Industrial production has of necessity been increased to a magnitude that has tested not only the ingenuity of research, men and machinery, but also of leadership, organisation and management. Applied in the direction of co-ordinating effort, organisation is the first step towards industrial planning; this, in turn, is the precursor of systematic production. Experience has shown that improved efficiency in industrial work can be effected by rationalisation, and in this report the author discusses the subject in two main sections—rationalisation in works generally and the application of the principles in a specific instance, viz., iron foundries, the first of which is presented in this article.

FOR many years the iron foundry industry appeared to suffer greatly through the replacement of cast iron by other materials. This was largely due to rapid development of welding processes by which parts, previously produced as castings, could be built in mild steel from plates and sections; but developments with other materials, and to some extent the lack of plant development and of proper organisation of the foundry-work, were also responsible for these replacements. In recent years, however, a considerable change has been effected. A new spirit has been developed; gradually the uses of cast iron are being extended, and progress has been accelerated by war conditions. This has become possible partly as a result of improved co-operation within the industry, but largely from intensive scientific research and development of new and highly efficient types of cast iron during the last decade.

Under present conditions industrial works are hard pressed to execute the work expected from them, but what of the future? Opinions differ on whether careful consideration should be given *now* to problems associated with post-war reconstruction, or *after* the war has been decided. Yet there can be no doubt that there is special need for post-war planning in order that schemes may be put into operation without unnecessary delay. It is appreciated that the most fertile brains are concentrated on winning the war, but while this is of primary importance, the change-over from war to peace conditions will create chaos unless well planned schemes are put into operation in industry almost immediately. This applies to the iron foundry as much as to other sections of industry.

Few will deny that leadership, with organisation as an integral part, is the nerve centre of a successful business, and that, in peace-time, competition is its driving force. Without it no section of industry can survive. Whatever may be the future development it is not likely competition will be eliminated from commerce, and efficiency of organisation—coupled with enterprise—will always favourably decide the competitive issue. In times of peace those responsible for directing industry put their organising, productive and commercial ability against contemporary competition, from wherever it may come, and according to the degree of enterprise and leadership displayed in each unit of industry, efficiency in the end outstrips inefficiency.

In the change from war to peace conditions reorganisation of industry will present a special problem. Much has been done in the past to improve efficiency in industrial works by rationalisation, and this report summarises these endeavours to progress. The first part is concerned with principles which may be applied to industry generally, while the second part deals with the application of these principles in the specific case of iron foundries, in order that the subject may be considered in some detail, and more attractively to those in practice. This latter part will be presented in several sections in succeeding issues.

Part I.—Rationalisation in Industrial Works Generally

Fundamental suppositions when approaching industrial works for rationalisation include:—

1. When starting the examination of a works for rationalisation purposes the result of this investigation is completely unknown. It may be that a large economical success can be obtained, or that the profit will be only small, or even that there will be no profit at all. In the last case—which has by the way never materialised during the writer's experience—the originator of the investigation should not consider the work done as lost, as the certainty that everything possible is done in the works in question towards economical success is worth-while the trouble and costs. Experience has shown that under average working conditions it is possible to lower the costs of the goods between 15 to 25% while increasing the earnings of the workers/hour 10 to 15%.*

2. It would be a mistake to build up a "system of rationalisation" and to apply this to any industrial works under discussion. Each works has to be considered as an individual unit with an organisation especially fitted to it, and not "ready-made," if this organisation shall accomplish what can reasonably be expected. Its rationalisation means generally an improvement of organisation, it is obvious that doing rationalisation work according to a definitely fixed scheme could do more harm than good. In any case, technical, economical and psychological aspects, with their often-contradicting demands, must be taken into account and the best compromise found.

Nevertheless it is possible to develop some principal ideas with regard to rationalisation, and these will be pointed out in the following part of this report, in which special methods are discussed that are recommended for application in foundries.

3. It must always be kept in mind that rationalisation—like all organising work—means working out details and accumulating small individual profits, and that, therefore, rationalisation takes time, say from six months to two years, according to the size and the original conditions in the undertaking. In this character of rationalisation work it is not enough to give the necessary instructions for improvement, but to ensure that these instructions are actually carried out in the correct manner, at the correct time, and in the correct sequence.

4. A further conclusion from what has been pointed out under (3) is that an industrial consultant, called for rationalisation in an industrial works, cannot himself do the actual work, but must leave that to the management and staff of the works, limiting himself to being an instructor, adviser and guide, as well as perhaps, in the later stages of the work, a controller.

* It should be understood that figures given in this report originate from German experience, and cannot be applied to British conditions without further considerations.

It must, therefore, be his first and most important task to gain the confidence of all concerned so that they consider him as a friend and co-operator rather than as somebody tracing mistakes and imperfections, thus perhaps endangering their own positions. That will be greatly facilitated by his correct introduction to the management, as well as to the staff and workers. Neglect of this point may jeopardise the ultimate success of the inquiry.

Instruments of Rationalisation in Industrial Works

Rationalisation should be based on careful and systematic production research that goes on, at least partly, in the works, although it is rarely that this term is applied, and the internal connections between the various sides of this research work are rarely recognised. The purpose of this research work is to find out how far some modern principles of production can, and are applied, and whether it can be recommended to press on their larger use in future. These principles are mainly:—

(a) The development from jobbing work to series—and mass—production, limited by the demand on the market and the purchasing power of the public, but also very often rendered more difficult than necessary by unjustified peculiarity of the design, etc.

(b) The technical standardisation of raw materials, finished goods, equipment, tools, gauges, appliances, etc.

(c) The quick, but, most important, continuous and uniform flow of work through all departments and shops of the works.

(d) The manufacture of products "just good enough," i.e., satisfying all justified demands of the customers, but avoiding unnecessarily high quality and accuracy.

It is obvious that these principles are not independent of each other; on the contrary, they are so closely intertwined that it is nearly impossible to keep the above separation—here only made for easier understanding—when investigating an individual works in practice. Actually all four principles aim mainly at the same result—the increase of the turnover of the capital invested, one of the essential factors of economic success, as famous examples show, e.g., the works of Henry Ford.

It must, however, be pointed out that these principles generally understood under the slogans: "Mass production," "standardisation," "continuous flow of work," "production of the just good enough," have been discredited in public opinion by distorting the economically sound ideas behind them in exhibiting the bad consequences of their exaggeration. That should not prohibit the use of these measures as far as they are economical in an individual case.

The instruments of production research are studies of various kinds going on in the works partly as routine work, partly as special investigations. They can be summarised under the headings: (a) Testing and inspecting. (b) Organisation studies. (c) Work- and time-studies. (d) Costing studies.

(a) While testing is concerned with material of any kind, as delivered to the works by an outside supplier, i.e., raw material, auxiliary material or consumable stores, accessories, etc., and properties of the finished or saleable goods as stipulated in the terms of delivery, inspecting deals with the semi-finished and finished products from the point of view of the manufacturing process.

Testing and inspecting can be defined as the comparison of a condition, a quantity, dimension or effect, etc., as it actually is, with a condition, a quantity, dimension or effect, as it ought to be. It consists in short in comparing the actual with the ideal; and this ideal can, of course, not be the real, i.e., never obtainable one, but must, so to speak, be a practical ideal; the reasonable compromise between technical, economical and psychological viewpoints, which is identical to what should be understood

under the term "standard." For a standard, the uniform solution of a repeated problem, is the result of standardisation, perhaps defined as the regularisation or establishment of what is approved as good or valuable, and even shown by experience and consideration—weighing the demands of design, production and economics.

The deviations of the actual from the standard as stated by testing or inspecting should be used—not as a reproach to production, as it often happens exclusively, but first, of all as a guide for improving the manufacturing process or sometimes even for making sure whether the standard is still correct, or has to be changed owing to changed working conditions. That must be kept in mind carefully when organising the testing and inspecting departments.

(b) As to organisation studies, it is reasonable to state that they are unknown in too many works, since organising work is often considered to be so simple that it can be done satisfactorily without any detailed investigations, and even by people not specially trained. How wrong this opinion is could frequently be determined by developing an organisation plan of existing works showing the functions of each member of the staff, and his or her position to superiors and colleagues. It is almost the rule in works where organising activity has been considered as unimportant that overlapping of duties, contradictory instructions, or duplicate work for the same purpose, etc., can be found, which only too easily lead to quarrels, or at least ill-feeling, between staff members, and result in waste of energy.

What actual measures may result from these organisation studies cannot be stated generally; they may lead to a regrouping of duties, eliminating of superfluous work, widening of bottle-necks of the clerical apparatus, bridging of gaps between measures in various departments, etc. In any case it will become obvious that organising work is not something which can be done once in a works, but that constant supervision and observation is necessary to discover whether changing conditions necessitate new measures, instructions and arrangements. Whether the managing director or general manager considers this function as his own duty, or delegates it to an organising superintendent, will depend on the extent and nature of the works, and the character of the persons concerned, etc. In any case this organising activity calls for a special gift of tactful treatment of people, otherwise instead of assisting in the main purpose of organisation the work may be seriously hampered.

(c) The work of the time study engineer is perhaps the most disputed in industry. While there are in both parties, management and workers, some who refuse it completely, there are others who propose to use it as a universal remedy in all difficulties, and all shades of opinion can be met between these two extremes.

The writer, who has devoted many years of his professional life to theory and practice of this problem, would like to warn against any exaggeration. Time studies are an excellent instrument of production research, perhaps in some cases the only one that could be recommended, but, like all instruments, it can do useful work only in the hands of a careful expert; and such an expert is not created by putting a stop-watch in the hands of a man who has just finished his apprenticeship in an industrial works, or taken a degree at a technical university. This job needs a thorough training, in addition to the experience of working in a shop similar to that where the studies are to be made, and a series of properties of character not always combined in one person.

Without going into any details concerning the essence of time studies—which would greatly surpass the reasonable extent of this report—some features of a general nature may be pointed out which are too often overlooked, as this fact may have greatly attributed to the distrust this excellent method of production research still meets in some circles.

As time studies were made originally with a view to assessing the payment of the men, the idea has gained ground that the development of fair piece-work wages is the main and perhaps the sole object of carrying out these studies. It must certainly be admitted that in many cases a reliable basis of piece-work rates cannot be found by any other means, but time studies are neither the only method for this purpose, nor are fair piece-work prices the only result of these investigations. On the contrary, to the writer's mind it is more important that this kind of research work should lead to improvements of production methods and processes which would never have been considered noteworthy and carried out if this systematic investigation had not taken place. In any case these improvements, especially a smoothly working organisation, are indispensable for introducing new or correcting unfair piece-work prices as the management should not ask the workmen to do more or better work unless it has done the utmost in his own province of work. If this point of view is accepted it may happen, as it has sometimes done in practice, that the introduction of piece-work wages or the correction of unfair piece-work prices could be abandoned completely and fixed hourly rates used. This is reasonable when the improvements have brought the plant to such a high technical standard that it is no longer necessary to use the wage system as an incentive. This result can be taken generally as a progress, and will be considered as pleasant by the workmen if the situation is explained to them correctly. Where, however, the system of piece-work rates must be considered as the solution of the given wage problem, the piece-work prices based on time studies are at least developed in the best manner known to-day, and can thus be regarded as fair as possible.

Furthermore, time studies can form a bridge between production on the one hand and costing and accountancy on the other. These functions are represented by departments of the industrial undertaking which are, unfortunately, frequently in opposition to each other. One can even say that the modern development of costing, as based on the idea of standard costs, could scarcely be put into practice without the help of time studies. As the same can also be said about standards, planning and its counterpart in money, budgeting largely depends on these investigations.

Last but not least, time studies are an excellent expedient for improving the psychological atmosphere in the works, for improving the mutual understanding between management, staff and men. This last statement is especially emphasised because, unfortunately, great mistakes in applying time studies were made in the early stages of this kind of work, and have created among the workers and their organisations a widespread antipathy, which must become the more ridiculous as the knowledge of applying time studies correctly enlarges, and the power of the trade unions increases to protect the men against the misuse of this excellent instrument of production research.

(d) For costing studies, it must be supposed that a thorough costing system is in action in the undertaking, showing clearly connection and distinction between costing and accountancy and allowing for a reasonable distribution and allocation of costs to the places or positions where costs originate, and to the jobs for which they are raised. The importance of standard costs has already been mentioned; they especially play a role in cost comparisons which are in many cases the subject of costing studies, either as internal comparisons between processes or production methods, in one and the same undertaking, or as external comparisons between similar methods in two or more different works.

With regard to rationalisation, costing studies have a special importance, as the economical success of any measure of rationalisation can be either anticipated or demonstrated afterwards only by comparing the respective costs.

If this general part of the present report seems to be rather lengthy, the reason is that it is thought necessary to show that rationalisation, i.e., the improvement of the working conditions of an undertaking should be started from different angles and with different means, which may be explained separately, but must be considered simultaneously in practice.

It is a mistake of many consultants that they specialise only in one of these aspects—e.g., speed of working, or clearness of statistics, etc. They develop this speciality and its instrument, e.g., time studies, or the costing system, etc., to a high perfection, but neglect other aspects. The result is an inequality of development, which may completely counterbalance the profit obtained by the partial improvement, or at least does not allow for the full success of the measures proposed.

Of course the fact that rationalisation should be considered as an indivisible whole for practical purposes renders the work more difficult, but that is no reason for repeating the mistake explained in the preceding paragraph when the close connections between the various points of view have been recognised.

Another reason for the rather elaborate form of the first part of this report is the wish to emphasise the spirit in which this work should be done; it is absolutely necessary to obtain the full co-operation of all concerned—management, staff and workmen; and this is only possible if they can be convinced that rationalisation will result finally not only in an increase of the economical success of the works, but also in an improvement of their own working condition and economical situation. It is true that obstinacy and ill-will can ultimately be overcome by compulsion, but this last remedy should be used only if absolutely necessary and after all attempts at friendly persuasion and conviction have failed.

Joint Council of Professional Scientists

A Joint Council of Professional Scientists representing over 10,000 qualified scientists, has been set up under the chairmanship of Sir Robert Pickard, F.R.S., by the Institutes of Chemistry and Physics in association with representatives of professional botanists, geologists, mathematicians and zoologists. The Council has been established to voice the collective opinion of qualified scientists on matters of public interest, to provide a liaison between professional organisations of scientists for co-ordinated action in matters of common interest, and in particular to concern itself with:—

- (i) The utilisation of scientists to the best advantage in the service of the community;
- (ii) the education, training, supply and employment of scientists;
- (iii) the better understanding of the place of scientists in the community;
- (iv) the maintenance of adequate qualifications and ethical standards among professional scientists;
- (v) the supply of information and advice to public and other bodies on matters affecting scientists.

This Council has been established for the period of the national emergency, but it may form the nucleus of some more permanent organisation to facilitate the close collaboration between professional men and women practising in all branches of science. Communications should be addressed to Dr. H. R. Lang, Honorary Secretary, Joint Council of Professional Scientists, c/o The Institute of Physics, at its temporary address, The University, Reading, Berks.

The Hon. J. S. McDiarmid, Manitoba Minister of Mines, reports that the discovery of chromite deposits 15 miles north-east of Lac du Bonnet may prove one of the most important in the province's mining history. He said that while the find has still to be tested, all preliminary reports are encouraging. Lac du Bonnet is situated 70 miles north-east of Winnipeg.

The Calibration of the Platinum/13%-Rhodium-Platinum Thermocouple over the Liquid Steel Temperature Range*

By C. B. Barber, B.Sc.

(National Physical Laboratory.)

The e.m.f.'s of eight platinum/13%-rhodium-platinum thermocouples have been measured at the melting points of gold, palladium and platinum by the wire method. On the basis of these determinations and the existing e.m.f./temperature relation up to 1,550° C., a reference table for the platinum/13% rhodium-platinum thermocouple covering the range 1,400° to 1,770° C. has been computed. It is estimated that the accuracy of the calibration in terms of the International Temperature Scale is $\pm 3^\circ\text{C.}$ up to 1,600° C. and $\pm 5^\circ\text{C.}$ beyond this temperature.

THE development of the quick-immersion technique for the use of platinum thermocouples for the measurement of the temperature of molten steel has now reached the stage when the method is being usefully employed for temperature control in steelmaking. In the preliminary experiments the absolute accuracy of calibration of the thermocouples was not of importance, but now that the method appears to be well established an accurate calibration is clearly desirable. Hitherto, platinum couples have not been used extensively above 1,550° C. on account of the relatively rapid rate of deterioration of the couple wires at such high temperatures, and thus there has been little demand for a calibration extending beyond this temperature. The present work has therefore been undertaken in order to provide e.m.f./temperature reference tables for the platinum/13% rhodium-platinum thermocouple over the range 1,400° to 1,770° C.

The temperature scale used in arriving at the calibration should be the International Temperature Scale, which is defined for temperatures above 1,063° C. by the melting point of gold (1,063° C.) and a value of 1.432 cm.-degrees for the constant C_2 in the Wien law of radiation, the disappearing filament optical pyrometer being the instrument normally used for realising the scale. Strictly, therefore, the calibration of a thermocouple over the range of temperature 1,400° to 1,770° C. involves a point-to-point comparison of the optical pyrometer and thermocouple, which at high temperatures is a difficult and lengthy process. As an alternative, however, indirect reference may be made to the International Temperature Scale by calibrating the thermocouples at fixed points which have already been determined precisely by means of the optical pyrometer. On the basis, therefore, of the melting points of gold (1,063° C.), palladium (1,555° C.) and platinum (1,773° C.) and the existing data of the thermocouple scale below 1,550° C., it is considered that a calibration of the thermocouple from 1,400° to 1,770° C. may be drawn up which will reproduce the International Temperature Scale with sufficient accuracy for present needs. This method of calibration is the one here adopted, and the details of the apparatus and measurements are given below.

Method and Apparatus†

The well-known wire method of calibration was used at all three fixed points. Although this method is sometimes considered not to yield such high accuracy as the ingot method, it can with certain precautions show a surprisingly

high precision, while it has the advantage of requiring only simple apparatus and a very small quantity of melting-point material. According to the method, a short length of the melting-point metal is joined between the ends of the two wires of the thermocouple under calibration (test couple) and placed, together with another couple (control couple), in an electrically heated furnace, the temperature of which is slowly raised, alternate readings of the e.m.f. of the couples being taken on a potentiometer. When the melting point of the metal is reached, the e.m.f. of the control couple continues to rise, while that of the test couple remains steady for a minute or two and then drops to zero on the breaking of the circuit due to the fusion of the metal forming the junction. The steady e.m.f. value immediately before the rupture is taken to be the e.m.f. of the couple at the melting point of the metal.

The measurements at the gold point are quite straightforward, but those at the higher temperatures may be subject to error mainly on account of the poor electrical insulating properties at high temperatures of the refractory materials of the furnace tube and thermocouple insulators. Thus, considerable error may arise by leakage from the furnace winding to the thermocouple circuit, should the wires be allowed to make contact with the hot furnace wall. In addition, an electrolytic effect appears to exist between thermocouple wires in contact with a refractory insulator at high temperature, revealing itself in the experiment by causing a high e.m.f., sometimes of the order of several millivolts, to be developed when the junction breaks. The following general conclusions were drawn from experiments conducted on the measurement of this e.m.f. and the circuit resistance under various conditions: That the effect exists both with a.c. and d.c. heating of the furnace, although smaller with the former; that reversing the direction of flow of the furnace current reverses the effect; that the resulting error is not likely to exceed a few microvolts. The phenomenon, with particular reference to the palladium point, has been discussed at some length by Fairchild, Hoover and Peters.¹ In the present measurement, inaccuracies on this account, and by reason of leakage from the furnace winding, were avoided by arranging that the insulators covering the thermocouple wires touched neither each other nor the furnace walls.

Eight thermocouples were calibrated, four being lent for the purpose by Messrs. Johnson, Matthey and Co., Ltd., and four by the Sheffield Smelting Co., Ltd. The couple wires, which were 0.5 mm. in diameter, were annealed by passing a current of about 13.5 amp. through them for about one minute. Each wire was threaded into a recrystallised alumina tube, 0.7 mm. in bore, of 0.5 mm. wall-thickness, and 150 mm. long, about 25 mm. of the wire

* Paper No. 17/1942 of the Committee on the Heterogeneity of Steel Ingots (submitted by the Liquid Steel Temperature Sub-Committee). Advance copy, published by the Iron and Steel Institute, December, 1942.

† A fuller description of the apparatus and details of the technique to be followed in making the measurements are given in the pamphlet, "The Technique of Calibrating Platinum Thermocouples for Use in Liquid Steel," London, 1942; H.M. Stationery Office.

¹ Bureau of Standards Journal of Research, 1929, vol. 2, pp. 959-962.

being left bare at the hot-junction end. The couples were mounted in pairs in clamps consisting of brass blocks having four parallel holes, into which the insulators were threaded and clamped at their ends by set-screws, so that they were held parallel to but not touching each other. A cross-section of this clamping block is shown in Fig. 1 together with a diagram of the furnace assembly. Two furnaces were used, one for the gold and palladium points and the other for the platinum points, each having a recrystallised alumina central tube, 12 mm. in bore, of 2.7 mm. wall-thickness, and 300 mm. long. The first-mentioned furnace had a spiral winding of platinum/10% rhodium foil, 12.5 mm. wide and 0.025 mm. thick, covering the whole length of the tube, a space of 1–2 mm. being left between the turns. The leads to the furnace winding each consisted of four strands of platinum wire, 0.5 mm. in diameter, welded to the ends of the foil. The platinum-point furnace had a winding of pure rhodium foil, 6.3 mm. wide and 0.075 mm. thick, with similar spacing of turns but covering only half the length of the tube, the long tube being used because a shorter one was not immediately available. As explained later, the greater length of the furnace winding employed for the gold and palladium points was on account of the need for greater temperature uniformity at these points than at the platinum point. The central furnace tube in each case was packed in alumina powder contained within a silica tube, which was in turn packed in Sil-c-cel powder. The outer diameter of the furnace case was about 200 mm. The approximate rating of the furnaces at each of the points was 10 amps., 15 v., at the gold point, 12 amps., 21 v. at the palladium point, and 16 amps., 17 v. at the platinum point. The furnaces were operated in the vertical position, the pair of test couples being lowered into them from above and adjusted so that the insulators were not in contact with the furnace wall, and the junctions were at the hottest part of the furnace. In order to be able to see into the furnace when making this adjustment, the metal block of the clamp had been cut away as shown in Fig. 1. An alumina disc was placed just below the test-couple junctions to reduce convection

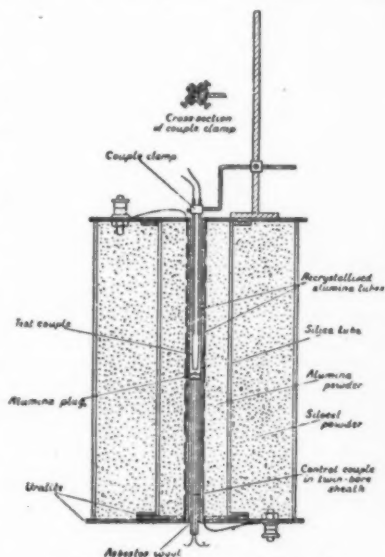


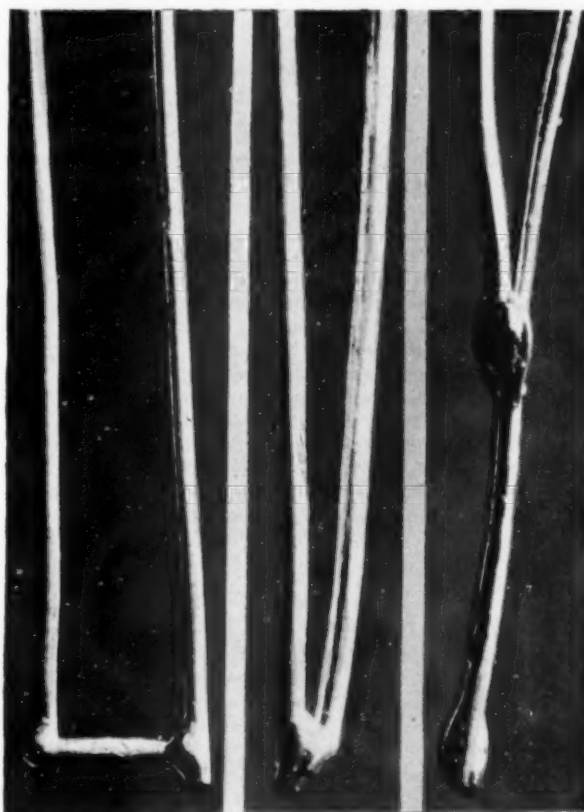
Fig. 1.—Furnace assembly for calibrating thermocouples by the wire method.

and radiation losses, and thus temperature gradients in the neighbourhood of the junctions. The control couple, mounted in a twin-bore insulator, was inserted into the furnace from below and placed with its junction adjacent to the disc which was supported by the twin-bore insulator. On the platinum-point experiments the control-couple junction was placed in a cooler part of the furnace, so that it remained intact when the test couples reached the melting point. The rate of the furnace temperature during the observations was adjusted to be of the order of 0.5° C. per min. for the gold point, and 1° C. for the palladium and platinum points. In order to be able to maintain this rate steady a reasonably constant voltage electrical supply was necessary. Since the furnaces used were small in size, and so of low-heat capacity, the mains supply was not

sufficiently steady, and it was found convenient to use a 50-v. battery. Larger furnaces could be operated on a less steady supply, but speed of adjustment of the temperature would be sacrificed on account of the greater thermal lag involved.

The gold and palladium wires were fused on to the ends of the thermocouple wires. Each junction was made by melting back the end of the gold (or palladium) wire in an oxy-coal-gas flame, so that the bead thus formed embraced the end of the thermocouple wire without the latter being melted. In this way it was possible to avoid extensive alloying of the two metals and the consequent errors due to contamination both of the melting-point metal and of the thermocouple wires. When the wire had been so joined it was about 3 mm. long. In Fig. 2 (a) a photograph of a gold-wire junction clearly illustrates that the ends of the couple wires have not been fused.

The experiment at the melting point of platinum is the same in principle, but no additional wire is here required since the melting-point material forms one arm of the



(a) Gold point, before melt. (b) Platinum point, before melt. (c) Platinum point, after melt.

Fig. 2.—Thermocouple junctions.

thermocouple. The thermocouple wires were fused together at the junction, and the position of the couple was adjusted in the furnace until the maximum e.m.f. reading was given, thus ensuring that the junction was at the hottest part of the furnace, and hence that fusion would commence at the junction. It was found that by arranging the bare couple wires projecting from the insulators to be close together (about 2 mm. apart) the platinum wire, after fusion at the junction, was still held in contact with the platinum-rhodium wire by surface tension of the bead, which moved up the alloy wire as the platinum arm melted back. The photographs in Figs 2, (b) and (c), illustrate the appearance of the junction before and after the experiment. Occasionally small irregularities on the surface of the alloy wire over which the platinum bead had passed seemed to indicate

that small quantities of platinum had been left behind, but, generally, the surface of the platinum-rhodium wire had retained its original polished appearance. This evidence, combined with the fact that the e.m.f. of the couple remained steady to within 2 or 3 microvolts, while the platinum arm was melting back some 1.5 cm., leaves little doubt that the melting point given was that of the pure platinum. In connection with this point Todd² has shown that two platinum wires twisted together melted at the same time as a platinum wire twisted with a platinum-rhodium wire, when heated side by side in a uniform-temperature enclosure.

A reasonable degree of uniformity of temperature in the neighbourhood of the hot junction is desirable in the case of the gold- and palladium-point determinations. It can be shown that a temperature difference of 1° C. between the ends of the palladium wire at the melting point will give rise to an error in the thermocouple reading of +25 or -35 microvolts, according to whether the palladium/platinum-13% rhodium or the palladium/platinum junction is at the higher temperature. In the case of such a violent gradient there would be no steady e.m.f. reading of the couple immediately before the break of the junction. The corresponding e.m.f. differences at the gold point are smaller, while at the platinum point they are non-existent. Although no special precautions were taken to ensure temperature uniformity in the furnaces employed, other than the use of a furnace tube having a high ratio of length to diameter, the steadiness of reading before rupture of the junction, and the reproducibility of the results were taken to indicate that there were no serious errors on this account. Subsequent experiments undertaken to throw further light on this point suggested that it was unlikely that an error exceeding ± 10 microvolts had been introduced from this cause.

The ratio of the electrical resistances at 100° and 0° C. of the palladium wire used was found to be 1.377, indicating a sufficiently high degree of purity.³ The values obtained for this ratio for the platinum wires of couples C₂ and 4 were 1.3916 and 1.3919, respectively. The Comité Consultatif de Thermométrie⁴ in 1939 recommended for adoption in the International Temperature Scale specifications that the ratio for the platinum used in resistance-thermometer bulbs and platinum/platinum-rhodium thermocouples employed in realising the International Temperature Scale shall have a minimum value of 1.391.

Discussion of Results

During the preliminary observations some of the couples gave lower values at the gold points after heating them to the platinum point than they did before. The platinum points in these cases were also unsatisfactory, no constant e.m.f. value being given, but the readings showing a steady rise during the fusion of the junction, which nevertheless was appreciably slower than that of the control couple. This seemed to indicate that these couples had become contaminated, their behaviour conforming to the supposition that the degree of contamination became less as the distance from the hot junction increased; thus, as the bead of platinum advanced up the alloy wire, a greater e.m.f. was given. The presence of this contamination could not be explained, and it was decided to reverse all the couples and recommence the observations.

The results of the observations on the reversed couples are set out in Table I, the four couples of one make being designated by the letters A, B, C and D, and the four couples of the other make by the figures 1, 2, 3 and 4. The figures in brackets after each value indicate the order in which the observations were taken. It is to be noted that a high reproducibility of reading at each point was obtained. The mean e.m.f. value of any one of the eight

couples does not differ from the mean of all the couples by more than 1° C. at any of the fixed points. The mean values of the two makes of couple at the palladium and platinum points differ only by the equivalent of 0.3° C., but at the gold point the difference is about 1° C. This seems to indicate a slight difference in the form of the e.m.f./temperature relation of the two products; the difference, however, is so small that the mean value of all the couples may be used to draw up reference tables which

TABLE I.
SUMMARY OF E.M.F. VALUES AT THE MELTING POINTS OF GOLD, PALLADIUM AND PLATINUM.

Figures in brackets indicate the order in which the observations were taken.

Couple.	E.M.F. in Microvolts (for Cold Junctions, 0° C.) at Melting Point of—		
	Gold.	Palladium.	Platinum.
A	11347 (3) 11348 (5)	18188 (4) 18191 (6)	21095 (1) 21105 (2)
Mean	11347.5	18189.5	21100
B	11354 (3) 11351 (5)	18185 (4) 18189 (6)	21105 (1) 21111 (2)
Mean	11352.5	18187	21108
C	11352 (3) 11348 (5)	18185 (4) 18186 (6)	21108 (1) 21113 (2)
Mean	11350	18185.5	21110.5
D	11353 (3) 11352 (5)	18191 (4) 18200 (6)	21123 (1) 21134 (2)
Mean	11352.5	18195.5	21128.5
Means of Couples A to D ..	11350.5	18189.5	21112
1	11365 (2) 11363 (4)	18202 (3) 18201 (5)	21119 (1) —
Mean	11364	18201.5	21119
2	11371 (3) 11363 (5)	18189 (4) 18198 (6)	21119 (1) 21119 (2)
Mean	11367	18193.5	21119
3	11366 (3) 11367 (5)	18187 (4) 18187 (6)	21116 (1) 21113 (2)
Mean	11366.5	18187	21114.5
4	11363 (3) 11362 (5)	18199 (4) 18187 (6)	21116 (1) 21107 (2)
Mean	11362.5	18193	21111.5
Means of couples 1 to 4 ..	11365	18194	21116
Means of all 8 couples	11358	18192	21114

may be employed with both makes of couple without introducing a significant error.

Table II, giving the mean e.m.f.'s of the thermocouples for every 10° C. from 1,400° to 1,770° C., has been derived from the data in Table I in the manner explained below.

TABLE II.
E.M.F./TEMPERATURE CALIBRATION OF PLATINUM-13% RHODIUM-PLATINUM THERMO-
COUPLES OVER THE RANGE 1400° TO 1770° C. WITH COLD JUNCTIONS AT 0° C.

The e.m.f. values are given to the nearest 0.01 mV., but the absolute accuracy is not claimed to be better than $\pm 3^\circ$ C. up to 1600° C. and $\pm 5^\circ$ C. above this temperature.

NOTE.—When compensating leads are used, care should be taken to ensure that the two junctions between the compensating leads and the thermocouple wires are at the same temperature, and that this temperature does not exceed 100° C. Otherwise, serious errors may be introduced.

Temperature.	1400° C.	1500° C.	1600° C.	1700° C.
° C.	MV.	MV.	MV.	MV.
0	16.00	17.43	18.81	20.16
10	16.15	17.57	18.95	20.29
20	16.29	17.71	19.08	20.42
30	16.43	17.85	19.22	20.55
40	16.58	17.98	19.35	20.68
50	16.72	18.12	19.49	20.81
60	16.86	18.26	19.62	20.94
70	17.00	18.40	19.76	21.07
80	17.14	18.54	19.89	—
90	17.29	18.67	20.02	—

As already stated, the relation of temperature to e.m.f. of a thermocouple should strictly be derived by comparison with an optical pyrometer reproducing the International Temperature Scale. It is known that in the case of platinum thermocouples, of a kind containing either 10% or 13% of rhodium, this relation cannot be expressed in linear or parabolic form on the basis of observations at the

² *Metal Treatment*, 1939, vol. 5, No. 20, p. 172.

³ *Proceedings of the Royal Society*, 1936, A., vol. 155, pp. 303-305.

⁴ *Procès-Verbaux des Séances du Comité Consultatif de Thermométrie*, 1939, Paris, 1939; Gauthier-Villars, Imprimeur-Libraire du Comité International des Poids et Mesures.

three melting points of gold, palladium and platinum. When, however, the range is considerably shorter than from 1,063° to 1,773° C., and the highest accuracy is not demanded, a parabolic form no doubt suffices. The following procedure has been adopted in deducing such a form over the range from 1,400° to 1,770° C.; for two of the three points required, the e.m.f. determinations at the palladium and platinum points are used. The gold-point observations are not directly employed, but by comparing them and the palladium-point observations with the interpolation curve used by the National Physical Laboratory for such couples for the range 1,063° to 1,555° C., an estimate is obtained of the e.m.f. value at 1,400° C., which is then used as the required third point. Since the above-mentioned interpolation curve agreed with those adopted in other laboratories to within the accuracy now aimed at, namely

$\pm 3^\circ \text{C.}$, this procedure may be regarded as satisfactory. It yields the following equation for the e.m.f./temperature relation from 1,400° to 1,773° C.:—

$$e = -7966 + 19.820t - 0.001928t^2.$$

From this equation the values in Table II have been computed. It is estimated that the accuracy of the calibration in terms of the International Temperature Scale is $\pm 3^\circ \text{C.}$ up to 1,600° C., and $\pm 5^\circ \text{C.}$ beyond this temperature. The calibration of a particular couple may be obtained by the determination of its e.m.f. at two points within the range, most conveniently the melting points of palladium and platinum, by the wire method, and plotting the curve of deviation from the reference table.

The work described in this paper was carried out at the National Physical Laboratory on behalf of the Iron and Steel Institute.

An Apparatus for Carrying out Bend Tests on Metal Sheet Strips*

By G. H. Glaysher

SOME specifications for sheet material carry a clause stating that the sheet shall be capable of being bent through an angle of 180°, round a former whose radius is: $R = AT$, where T is the thickness of the sheet and A a specified co-efficient (which in some cases is 10 or smaller).

the value of T in the first group varying between 0.08 and 0.11 in., in the second between 0.055 and 0.065 in., in the third between 0.035 and 0.045 in., and R was to vary between $10T$ and $1T$.

The sheets were measured to the nearest $\frac{1}{1000}$ in., but in order to reduce the very large number of formers that would have been necessary were a separate one required for each $\frac{1}{1000}$ in., it was decided to allow a uniform tolerance of $\pm \frac{1}{10000}$ in. It was calculated that 42 formers varying in diameter from 2.1 to 0.074 in. would enable the full series of tests to be carried out, and the apparatus described below was designed for this purpose.

Briefly, the machine consists of a clamp to hold the test-piece tangentially to a selected former, around which is rotated a roller that bends the metal through a radius of 180°. To ensure a steadily applied pressure, rotation is made by a small hand wheel through suitable worm gearing.

In construction, the machine consists of a steel plate A (Fig. 1), mounted on supports and capable of being secured to a bench. On the upper side of the plate A the raised steel frame B is rigidly supported. Beneath the frame B is a clamp C with adjustable jaws sliding in guide bars; these jaws are adjusted by the set screws D. An extension of the frame carries a hardened steel bush which serves to locate the pin E; this in turn locates the former F. The pin E also serves as an axis around which the arm G rotates; on arm G, a roller H is mounted which is free to rotate, also to be adjusted radially, and clamped in contact with the test-piece. The arm G is fixed to the worm wheel J situated on the underside of plate A; a boss on the worm wheel passes through the plate A and provides the necessary bearing, a hole in the centre of the worm wheel serving as an additional bearing for the pin E.

The worm wheel J, to which is attached the arm G, is rotated through an angle of 180° by the worm K, which is connected to the hand wheel L. Concentric with the former F and at the end of the arm G, a graduated scale is fixed to the plate A.

The formers from 2.1 to 0.32 in. inclusive are metal discs or sleeves the width of the test-piece ($\frac{1}{2}$ in.), accurately machined to the required diameter, with a central hole to accommodate the pin E. For the diameters 0.25 to 0.074 in. the pin E is used as a former, the required diameters being obtained by reducing the pins at the portion occupied by the test-piece.

The apparatus was designed in connection with the research programme of the National Physical Laboratory.

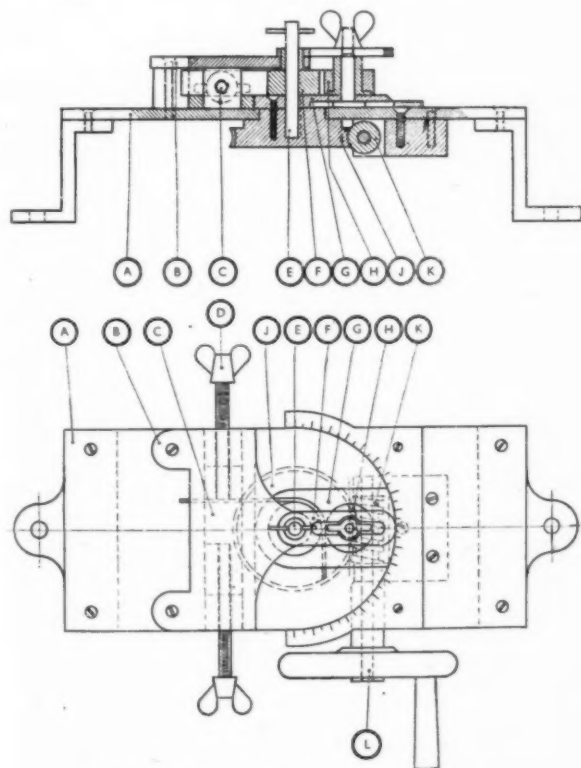


Fig. 1.—Bend test apparatus for sheet strips.

In some work on magnesium alloy sheet a machine was required to determine the lowest value of R around which this sheet would bend through 180° without failure; and also, should failure take place, the angle at which it occurs. The sheets were in three groups of thickness,

*Reprinted from *Jour. Inst. Metals* (December, 1942) 66, 383.

A Metallurgical Study of German and Italian Aircraft Engine and Airframe Parts

THIS report constitutes a summary of data resulting from the metallurgical examination of German and Italian aircraft engine and airframe parts by the Aero Components Sub-Committee of the Technical Advisory Committee to the Special and Alloy Steel Committee formed for this purpose. In this, the ninth of the series, is presented a summary of the results of investigations on miscellaneous parts, including fuel injection pumps, hydraulic clutches, supercharger parts, spiders and airscrew hubs; part of a section dealing with airframe components is also included.

The Sub-Committee responsible for these investigations and for this report comprise Mr. W. H. Dyson, Ministry of Aircraft Production; Dr. H. Sutton, Royal Aircraft Establishment; Dr. R. Genders, Superintendent, Technical Applications Metals, Ministry of Supply; Mr. H. Bull, Messrs. Brown-

Bayley's Steelworks, Ltd.; Mr. H. H. Burton, The English Steel Corp., Ltd.; Mr. W. J. Dawson, Messrs. Hadfield, Ltd.; Dr. W. H. Hatfield, F.R.S., Chairman, Brown-Firth Research Laboratories; Mr. D. A. Oliver, Messrs. Wm. Jessop and Sons, Ltd.; Dr. T. Swinden, the United Steel Companies, Ltd.; and Mr. G. Stanfield, Secretary, Brown-Firth Research Laboratories.

The work included in this report embraces the results of investigations carried out from the beginning of the war until towards the end of 1941, but investigations have continued and are still in progress, and the work is being carried out meticulously. Naturally, no comparisons are made in the report with corresponding parts in British or American aircraft, neither are certain aspects, which the investigations have shown to be open to criticism, emphasised.

Section XI—Miscellaneous Engine Parts

THE parts considered in this section comprise:—(A) Fuel injection pump barrel and plunger; (B) Hydraulic clutch; (C) Supercharger parts; (D) Spider; and (E) Airscrew hubs.

A.—FUEL INJECTION PUMP BARREL AND PLUNGER

Two such parts have been examined: (1) from a Mercedes-Benz D.B. 601A engine (Report No. 73), and (2) from a Jumo 211F.1 (Report No. 121). A summary of the essential details are given in Table I.

Figs. 1 and 2 illustrate the pump parts from both engines. The design is somewhat similar in each case, although certain small variations can be seen. The plunger of each type was a close, sliding fit into the barrel, and in each case the surfaces had a smooth lap finish.

Composition

Both components from the Mercedes-Benz consist of a direct hardening 1% carbon, 1½% chromium steel; while those from the Jumo 211F.1 were case-hardening types of steel. The plunger was a 1% chromium-molybdenum type, but the barrel was a plain carbon steel with 0.18% carbon. Both types of pump were case carburised.

Method of Manufacture

All the analyses suggested that the parts had been made by the basic electric-arc process.

Cleanliness

In each case the cleanliness was considered to be reasonably good, and the following inclusion counts were recorded:

	Barrel.	Plunger.
Mercedes-Benz D.B. 601A	40	49
Jumo 211F.1	46	28

Inherent Grain Size

While the Mercedes-Benz parts were found to be of the fine-grain type (6 to 7),

the Jumo parts were somewhat of a coarser rating, namely, the barrel was 4 to 6, with a few coarser grains, and the plunger was 1 to 4 (mainly, 3 to 4).

Hardness

The following hardness values were obtained:—

	Surface.	Core.
Jumo 211F.1 Barrel.	882—912 D.H.	216—221 D.H.
Plunger.	849—869 D.H.	456—459 D.H.

TABLE I.—COMPOSITION, GRAIN SIZE

Report	Type of Engine	Component.	C.	Si.	Mn.	S.	P.	Ni.
73	Mercedes-Benz D.B. 601A	Fuel Injection Pump.						
		Barrel	1.01	0.25	0.29	0.013	0.014	0.02
		Plunger	0.99	0.26	0.25	0.010	0.013	0.02
121	Jumo 211F.1	Fuel Injection Pump.						
		Barrel	0.18	0.30	0.36	—	—	0.07
		Plunger	0.19	0.21	0.82	—	—	0.36
92	Mercedes-Benz D.B. 601N	Hydraulic Clutch.						
		Casing	0.15	0.26	0.92	0.012	0.010	0.13
		Cover-plate	0.12	0.35	0.51	0.030	0.022	0.21
		Rotor body	0.40	0.34	0.86	0.017	0.014	0.20
		Rotor shaft	0.25	0.35	0.88	0.019	0.032	0.30
		Ball-bearing						
		Outer Race	0.96	0.29	0.29	0.014	0.017	0.05
		Race Balls	1.10	0.31	0.20	0.017	0.020	0.02
		Clamping rings	0.26	0.27	0.61	0.011	0.007	0.32
		Retaining ring	0.35	—	—	—	—	—
		Steel bearing	1.09	—	0.26	—	—	—
54	ME 110 D.B. 601A	Super-charger Intake.						
		Sheet	0.10	0.02	0.31	0.018	0.008	0.06
		Vanes	0.11	—	0.38	—	—	—
63	Fiat A. 80/R.C. 41	Spider	0.31	0.40	0.68	0.009	0.013	2.96
61	Mercedes-Benz D.B. 601A	Airscrew hub	0.32	0.28	0.36	0.005	0.017	1.24
62	Fiat A. 80	Airscrew hub	0.42	0.34	0.65	0.011	0.018	0.13

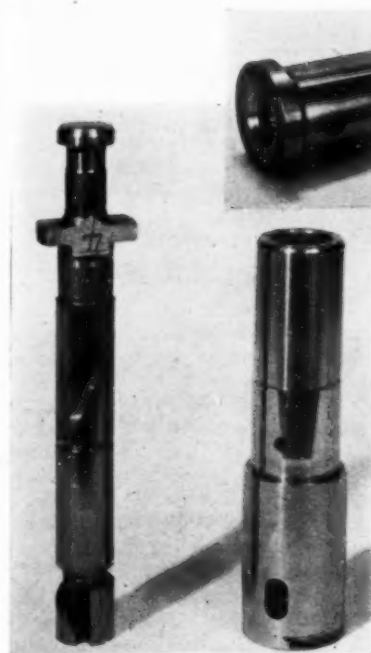


Fig. 1.—Pump plunger and barrel of Mercedes-Benz D.B. 601A.

The core strengths of the Jumo barrel and plunger approximated to 47 and about 94 tons, respectively.

Metallographic Examination

The D.B. 601A barrel and plunger were both in the hardened and lightly tempered condition, the latter having a pronounced banded structure.

Both the barrel and the plunger of the Jumo 211.F.1 pump were carbon case-hardened, the depth of case in each sample being 0.03 in. (Fig. 3). The etched structures were satisfactory (see Figs. 4 and 5).

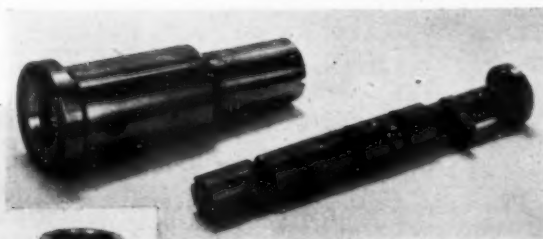


Fig. 2.—Pump barrel and plunger of Jumo 211.F.1.

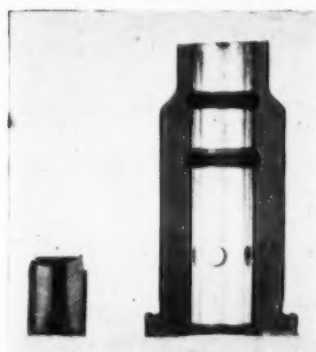


Fig. 3.—Section of Jumo 211.F.1 pump barrel and plunger, showing case.

The grain flow showed that all the parts had been machined from bar stock.

B.—HYDRAULIC CLUTCH Mercedes-Benz D.B. 601N.

Only one clutch was examined, and details are given in Table I. Fig. 6 illustrates a general view of the clutch, while Fig. 7 shows an external view of the rotor and cover-plate separated from the casing. Fig. 8 is a view of the sectioned clutch.

The surface finish was originally smoothly machined and polished, but a

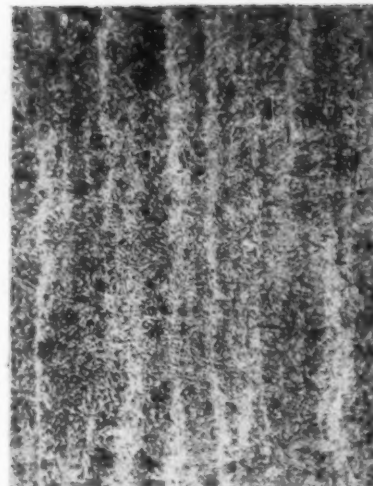


Fig. 4.—Etched structure of Mercedes-Benz D.B. 601A plunger. x 200.



Fig. 5.—Etched structure of Jumo 211.F.1 barrel. x 50.

AND HARDNESS OF COMPONENTS

Cr.	Mo.	V.	Cu.	Al.	Ti.	Grain Size.	Diamond Hardness.		Special Remarks.
							Case.	Core.	
1.33	Nil	Nil	—	—	—	6 to 7	—	813/823	Case carburised
1.42	Nil	Nil	—	—	—	6 to 7	—	823	Case carburised
0.07	Nil	Nil	Trace	—	—	4 to 6 (a few coarser grains)	882/912	216/221	Case carburised
1.4	0.20	Nil	0.08	—	—	1 to 4 (mainly 3 to 4)	849/869	456/459	Case carburised
1.03	0.21	—	—	—	—	Erratic 3 (mainly 2 to 4)	666/687	275/320	Partially case carburised
1.64	0.37	0.15	—	—	—	6 to 7	—	303/312	Inner similar
1.70	0.17	0.18	—	—	—	6 to 7	—	364/371	
1.22	0.27	—	—	—	—	Erratic 2 (2 to 3 with some 1)	766/802	448/458	
1.37	0.03	—	—	—	—	—	—	797/814	Inner similar
0.02	0.01	—	—	—	—	—	—	845/859	
0.90	0.21	—	—	—	—	3 to 4	—	150/156	
1.22	0.30	—	—	—	—	—	—	213	
1.45	0.02	—	—	—	—	—	—	779	
0.04	Nil	Nil	0.05	—	—	—	—	111/119	
—	—	—	—	—	—	—	—	72/98	
0.07	0.40	Nil	0.05	—	0.026	6	—	401/424	
1.88	0.38	Nil	0.05	—	—	4 to 5	—	298/315	
0.09	0.18	Nil	0.065	—	0.007	2 to 4	—	283/324	

large part exhibited discolorations similar to temper colours, and the examination suggested that the clutch had run hot at some stage.

The following remarks apply only to the four main parts, viz., the casing, rotor body, rotor shaft, and cover-plate.

Composition

The parts were all made from chromium-molybdenum steels, but three different compositions were involved (see Table I), one of which contained vanadium. The molybdenum contents were rather varied.

Method of Manufacture

With the exception of the cover-plate, which contained 0.030% sulphur, the steels were probably of basic electric-arc manufacture. All parts were made as forgings. The macrostructures of the rotor body and rotor shaft, respectively, are illustrated in Figs. 9 and 10.



Fig. 6.—General view of Mercedes-Benz D.B. 601N clutch.

Fig. 7.—External view of rotor and cover-plate, Mercedes-Benz D.B. 601N.



Fig. 8.—View of sectioned hydraulic clutch, Mercedes-Benz D.B. 601N.

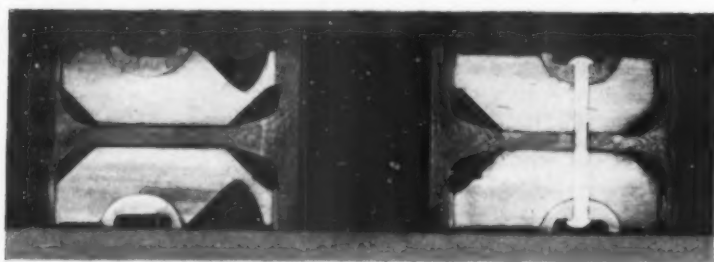


Fig. 9.—Macrostructure of rotor body, Mercedes-Benz D.B. 601N.



Fig. 10.—Macrostructure of rotor shaft, Mercedes-Benz D.B. 601N.

Inherent Grain Size

The McQuaid Ehn test showed two of the parts (casing and rotor shaft) to be of the coarse-grain type, while the other two could be classed as fine-grain steel.

Cleanness

The lower sulphur steels compared reasonably well with the British Standards for aircraft steels. The cover-plate also compared quite well except for the differences in sulphur content.

Hardness

Hardness tests showed the casing to have been case-hardened along the length of the splined portion, and for a short distance along the shaft. In addition to which the rotor shaft was case-hardened on the whole of its outer surface except for the two threaded portions. Table I should be consulted for the hardness values.

Microstructure

Both the cover-plate and the rotor body had been hardened and had fully tempered structures. The casing was carburised locally at the splined end of the shaft, and the case showed the presence of free carbide in martensite. The rotor shaft also was carburised, and both case and core showed markedly acicular martensitic structures with no free carbide present. The carbon content of this material is rather high for carburising steel.

The rotor shaft part was discussed in Section VIII.*

Subsidiary Parts

A number of non-ferrous components were examined but are not included in this report. They were as follows:—

- (a) Impeller inserts—aluminium-silicon alloy.
- (b) Three bearings—copper alloy with iron, nickel and aluminium.
- (c) Cage from ball bearing—copper-aluminium alloy.

Details of other steel parts are included in Table I.

C.—SUPERCHARGER PARTS

These comprise the following:—

- (1) Supercharger driving sleeve (B.M.W. 132K engine) (Report No. 30).
- (2) Supercharger intake D.B. 601A (ME 110) (Report No. 54).

A summary of the examinations will be found in Table I.

(1) *Supercharger Driving Sleeve.*—Details in connection with the supercharger driving sleeve (Report No. 30 above) will be found in Section VIII,* where it is discussed under the heading of "Gears."

(2) *Supercharger Intake.*—Figs. 11 and 12 show two different views of the supercharger intake. The whole of the component had been built up by welding mild steel sheet with mild steel hollow vanes incorporated, all of which were in the annealed condition. The component had been lightly shot-blasted, and subsequently painted all over.

The non-metallic inclusions in the steel indicated a good-quality basic open-hearth steel, while the welds examined were good; all being reasonably sound and free from scoria.

* METALLURGIA, NOV. 1942

D.—SPIDER**Fiat A. 80R.C.41 (Report No. 63)**

This is a part from the variable pitch propeller mechanism, and only one example has been studied. Table I. gives a summary of the tests carried out.

General Features

Fig. 13 illustrates the outline of the spider.

The whole of the outer surface, with the exception of the two parallel bearings on the three arms, was found to be cadmium-plated. Only small portions of the interior showed this feature.

Composition

The spider was made from a direct-hardening 3% nickel, 1% chromium, 0.4% molybdenum steel.

Method of Manufacture

The steel was of basic electric-arc manufacture, and the part had been made as a forging. Comparison with the flow structure of British forgings of this type indicated that the Italian forging was appreciably inferior (see Fig. 14).



Fig. 13.—Outline of the variable-pitch propeller spider for Fiat A. 80R.C.41.



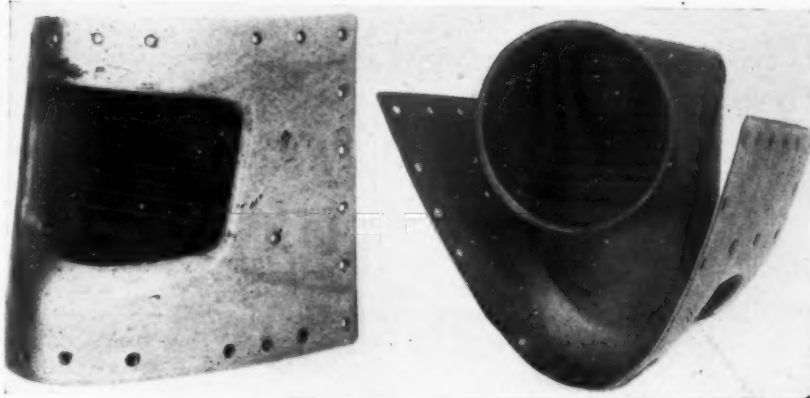
Fig. 15.—Outline of airscrew hub of Mercedes-Benz D.B. 601A.

Inherent Grain Size

This test showed the material to be of the fine-grain type (No. 6).

Hardness

This was fairly uniform at 401 to 424 D.H.



Figs. 11 and 12.—Supercharger intake for Mercedes-Benz D.B. 601A.

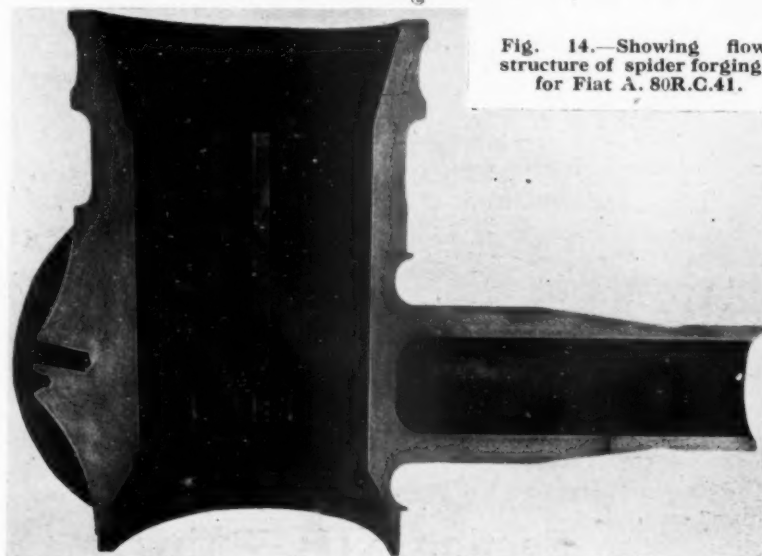


Fig. 14.—Showing flow structure of spider forging for Fiat A. 80R.C.41.

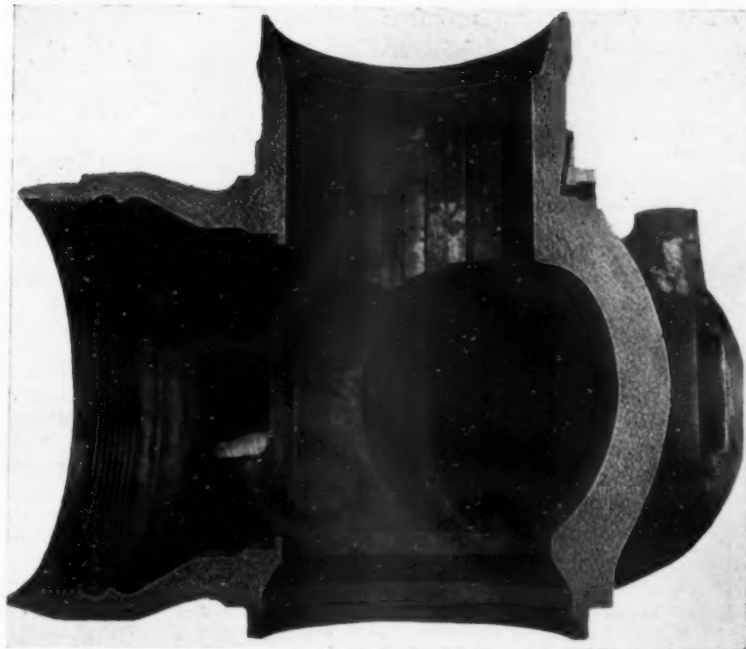


Fig. 16.—Structure of hub forging of Mercedes-Benz D.B. 601A.



Fig. 17.—Outline of airscrew hub of Fiat A. 80R.C.41.

Cleanness

The steel was similar in this respect to the average quality of British aircraft steels.

Micro-examination

A sorbitic structure typical of hardening and tempering was observed.

E.—AIRSCREW HUBS

Two types have been examined, one being from a Mercedes-Benz D.B. 601A engine (Report No. 61), and the other from a Fiat A. 80R.C.41 type (Report No. 62). A summary of the detail is included in Table I.

General Features

The two hubs differed in that the German example was made as a solid



Fig. 18.—Structure of part of hub forging of Fiat A. 80R.C.41.

component whereas the Italian part consisted of two separate alignable parts almost identical in design, except that the centre aperture was circular in one case and hexagonal in the other.

Both hubs were cadmium-plated.

Figs. 15 and 17 illustrate the form of the parts.

Composition

The German hub was found to have been made from a 2/2 nickel-chromium-molybdenum steel, but the Italian one was a 1% chromium-molybdenum type.

Method of Manufacture

Both types of steel were representative of the basic electric-arc process, and both hubs had been made as forgings. In the case of the German one, the hub had first been made as a forged block and an axial hole had probably been punched or pierced during forging. The bulk of the metal removed from the

interior had been accomplished by machining (see Fig. 16). Examination of the Italian hub showed that it had been made as two separate drop forgings to a contour closely following that of the finished article. (See Fig. 18.)

Inherent Grain Size and Cleanness

The grain sizes in both cases were medium to fine. With regard to the cleanness, while the German steel represented good-quality basic electric-arc material, the Italian steel was relatively poor.

Hardness

In both instances the hardness values were fairly uniform at approximately 300 D.H.

Micro-Examination

Both structures indicated a hardening and tempering treatment.

Section XIII.—Airframe Components

A.—WELDED STEEL ENGINE MOUNTINGS

The components examined were as follows:—

- (a) B.M.W. 132K engine (Report No. 58).
- (b) B.M.W. 801A engine (Dornier 217E.1 aircraft) (Report No. 130).
- (c) Bramo Fafnir 323P engine (Report No. 59).

In (a) and (c) the mountings were essentially of tubular welded steel structure comprising an engine ring, with attachments for a radial engine and struts connecting it to four points on the airframe.

The other B.M.W. mounting (b) did not include a ring tube, and was incomplete.

Construction

(a) *B.M.W. 132K Mounting.*—A general view is given in Fig. 1. The six strut tubes are attached to the tubular ring at three points, at two of which hollow formed or box fillets are used (see Fig. 2). Fig. 3 shows a joint

of two tubes to the ring without the use of hollow fillets. Nine tubular lugs are welded longitudinally to the inside of the tubular rings to take engine bolts. The two rather massive feet at the airframe end, to each of which two of the struts are attached by welding, consist of a central threaded portion machined from the solid, round which the foot has been built up by welding, as shown in Fig. 4.

The ring is closed by a simple butt joint.

(b) *B.M.W. 801 A/1 Mounting.*—A general view is shown in Fig. 5. Two portions comprise the mountings, the larger piece forming a rough M, of which the two higher points form two similar built-up feet (Figs. 6 and 7), whereas the centre point appeared to form a different type of connection (Fig. 8). In the smaller piece, the two broken strut tubes meet to form a foot similar to that shown in Fig. 6, except that the foot assembly is missing.

(c) *Bramo Fafnir 323P Mounting.*—A general view of the mounting is given in Fig. 9. The engine ring is connected

to the airframe by eight struts which are joined in pairs at the rear, airframe end. At the engine-ring end two of the struts are joined to the ring by simple welded T-joints, but the rest of the struts meet in pairs at the ring, and at two of these multiple joints side-plates are welded on for reinforcement on both inner and outer sides of the joint. No formed fillets are used in any of these joints. Figs. 10 and 11 show joints of struts to ring without and with side-plates.

To the inside of the ring nine pairs of formed lugs are attached by welding. Each pair of lugs carries a hollow steel bolt which passes through a thick rubber bush housed in a small built-up fitting which takes the engine attachment bolts. The ring is closed by a simple butt joint.

All the feet were similar, and a photograph of one is shown in Fig. 12.

Surface Finish

(a) *B.M.W. 132 K.*—Considerable variation of the condition of the tube surface was observed after removal of



Fig. 1.—General view of B.M.W. 132K engine mounting.



Fig. 2.—Box fillets used at two points of attachment.

the paint. The ring tube appeared to be lightly but uniformly scaled except for local sand-blasting at the welded lugs. The strut tubes appeared to have been sand-blasted in the vicinity of the welds, but were fairly uniformly scaled elsewhere. The bore of all the welded tubes was encrusted with a heavy rust growth, but the cross-bracing tube to the strut tubes was free from internal rusting. The whole of the external surfaces are coated with a grey-green paint, and on removing this it was observed that in several places the corrosion had penetrated the tube wall.

(b) *B.M.W. 801 A/1*.—All the surfaces were painted grey-green outside, under which the surfaces both at and away from the welds were sand-blasted. The bore surfaces were lightly sealed.

(c) *Bramo Fafnir 323P*.—The whole of the mounting is coated with aluminium paint applied over a thick undercoat of a comparatively soft varnish. The



Fig. 3.—A joint of two tubes without the use of box fillets.



Fig. 4.—One of the feet at the airframe end of the mounting.

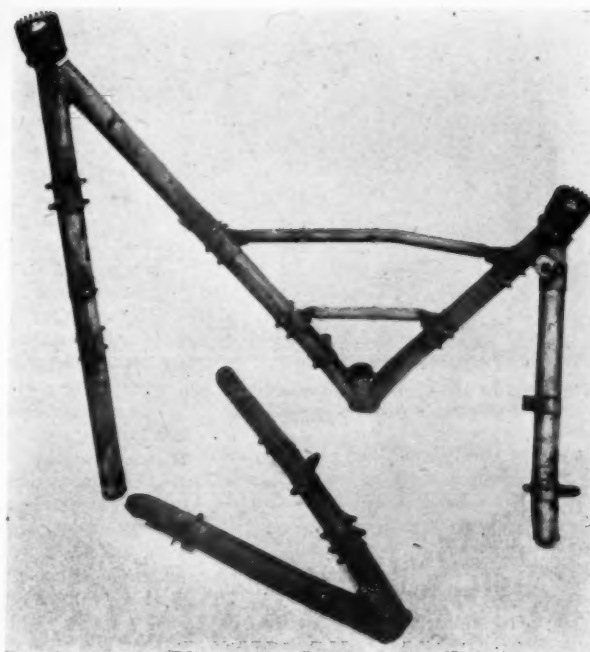
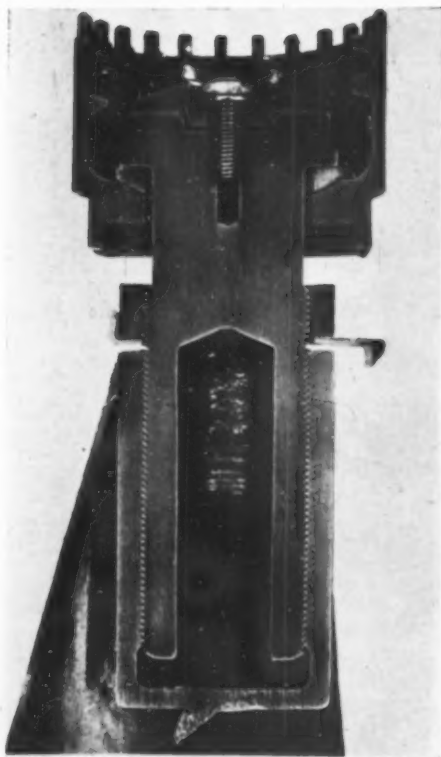


Fig. 5.—A general view of the B.M.W. 801A/1 engine mounting.



Figs. 6 and 7.—Outline and section of one of the two similarly built feet.

surface of the tubes, when cleaned free of paint, had a matt appearance, and appeared to have been sand-blasted. The tubes were found to be lightly but evenly sealed in the bore.

General Observations

The German mountings consisted of tubes, sheet, forgings and machined



Fig. 8.—Outline of a different type of connection forming the mounting.

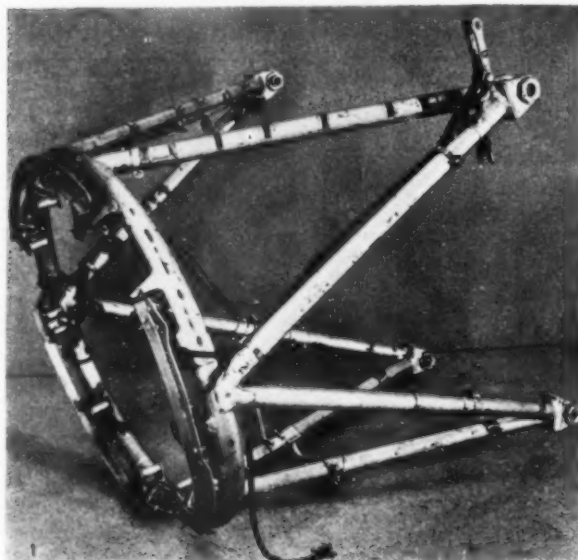


Fig. 9.—General view of the Bramo Fafnir 323 P. engine mounting.

parts in chromium-molybdenum steel containing about:—

Carbon	0.20 to 0.28
Chromium	1.0
Molybdenum	0.20 to 0.25

The majority of the subsidiary parts such as brackets and engine bolts were made in the same steel.

The material was clean and of low sulphur content, and was probably of basic electric-arc manufacture. The inherent grain size was in the main fairly fine. The mountings were assembled by oxy-acetylene welding without subsequent heat-treatment. Micro-examination showed that the tubes were in the normalised condition prior to welding in both the B.M.W. and Bramo Fafnir mountings. The tensile strength of the tubes was of the order of 47 to 50 tons per square inch, and the ductility was reasonably good, as shown by flattening tests. Some of the welds in the complex feet of the B.M.W. 132K mounting,

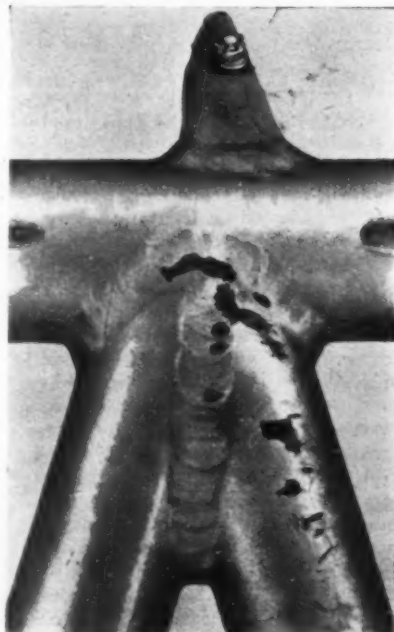


Fig. 10.—Showing joint of strut to ring without side-plates.

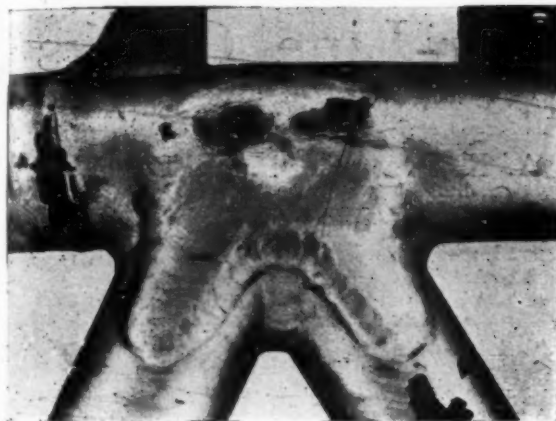


Fig. 11.—Showing joint of strut to ring with side-plates.

and the welds in the bracket carrying rubber bushes, showed that these units had been normalised after welding.

The deposited metal in the welds of the German mountings was also chromium-molybdenum steel, but con-

tained less chromium (0.75%) than the tubes. The hardness peaks, due to rapid cooling near the welds, were not severe, the highest values observed being of the order of 351. The tubular lugs carrying the engine attachment bolts on the B.M.W. 132K mounting ring, to which they are attached by fillet welds and the formed

lugs on the Bramo Fafnir mounting, exemplify the important duty some of the welds have to perform in these mountings.

(Continued in February issue.)

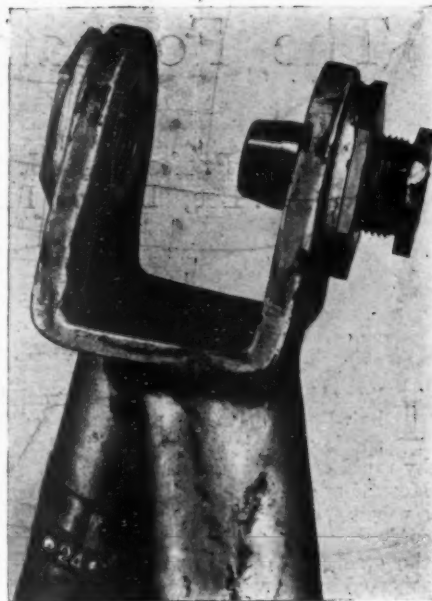


Fig. 12.—One of the feet formed on this mounting.

Selecting Alloy Steels

A USEFUL practical guide has been prepared by Mitchell* which shows the trend of influence of certain alloying elements when added to plain carbon steel, such as those containing 0.05 to 0.10% carbon, 0.15 to 0.25% carbon, or 0.25 to 0.35% carbon. The scheme suggested applies only to steels of fine grain. It is provided by means of a chart, which is reproduced below.

In this chart the rating numbers vary from zero to +10 where the element is

favourable, and from zero to -10 where use of the element is detrimental. P means that the effect is proportional to the amount of the alloy. S means small quantities are most effective. L means large quantities, near the top of the range, are needed. I signifies that intermediate amounts are most effective; +(?) means probably positive influence; -(?) means probable negative influence. It should be remembered that merit numbers are generally based

upon use of the maximum percentage shown for each element.

The toughness ratings are based on standard V-notched impact for heat-treated steels. When the chart is used to arrive at the most suitable steel for a certain application, all the favourable and unfavourable points for the properties involved should be summed up so that the user can determine which alloying elements will give best results.

At present, the trend is to standardise on fewer types of steels and to use smaller amounts of alloying elements.

EFFECT OF ALLOY ELEMENTS ON PROPERTIES OF STEELS.

	C.		Mn.	P.	S.	Si.	Cr.	Ni.	Mo.	V.	Cu.
	0.1-0.3%	0.3-0.85%	0.25-2%	0.015%	0.03%	0.2%	1.1%	5%	0.75%	0.25%	1.1%
ANNEALING: Degree of accuracy necessary to control temperature when annealing lamellar pearlite	+3L	+5P	-2L	0	0	-2P	+3P	-5P	-3L	+2P	-(?)
CARBURISING: Depth of case only	0	-4P	+3P	0	0	-10L	+2P	-3P	-2P	+2P	-10L
CORROSION: In atmosphere or weakly corrosive liquids	-3P	-6P	0	+10P	-10P	+2P	0	+6L	+2P	0	+10S
CRACK RESISTANCE: At temperatures up to 350° F.—Steels drawn at higher temperatures	+2L	-3P	0	0	0	0	+1P	0	+10P	?	?
DISTORTION ON OIL QUENCHING and susceptibility to quench cracks	-1P	-2P	-4P	-3P	0	-1P	-4P	-2P	-3P	-1L	0
FABRICATION IN COLD BENDING	-2L	-10P	+2L	-10L	-7P	-6P	-10P	+5S	+2S	+3P	+2P
HOT WORKABILITY—formation of seams, scale, decarburised skin, resistance to flow	+2P	-7P	+7S	0	-10S	-3P	0	-6P	-3P	0	-10S
HARDENABILITY or hardness penetration (basis 0.7-1.0% Mn)	+1P	+2P	+10P	+3P	-2P	+2S	+7S	+10L	+7S	+5L	+(?)
MACHINABILITY: Steel annealed maximum lamellar pearlite	+2P	+3L	-2L	+6P	+10P	-2L	-2P	-10P	-4P	-1P	-(?)
TOUGHNESS: Steel fully quenched and tempered to 300 BHN	0	-1P	0	-5P	-3P	0	0	+6P	+2S	+1P	+(?)
TOUGHNESS AT -50° F.: Steel fully quenched and tempered to 300 BHN	0	-2P	0	-5P	-3P	0	0	+10P	+2S	+1P	+(?)
WEAR RESISTANCE: Steel fully hardened (no free ferrite) to Hc60, drawn at 300-400° F.	0	+10P	+6P	+1P	0	+2P	+8P	+3L	+5P	+2P	+(?)
WELDABILITY: Susceptibility to small ruptures when fusion welding without pre- or post-heating	-2L	-10P	-10L	-7L	-3P	-5L	-10L	-10L	-10L	+1P	-4L

* J. Mitchell, *Metal Progress*, 42, 1942, July, pp. 53-61.

The Formation of Hair-Line Cracks

Part II*

By Professor J. H. Andrew, D.Sc., A. K. Bose, B.Met., Ph.D.,
H. Lee, B.Eng., Ph.D., and A. G. Quarrell, Ph.D., F.Inst.P.

The work reported in this paper is mainly concerned with the role of hydrogen in the production of hair-line cracks. Specimens of a number of steels were treated in hydrogen at 1,200° C., followed by water-quenching, have been examined, and it is concluded that hydrogen is the fundamental cause of hair-line cracks. The authors' discussion of results from the investigation is given together with their conclusions.

IT was shown in Part I¹ that internal defects similar to hair-line cracks could be produced by soaking steel specimens in hydrogen at a high temperature, followed by rapid cooling and ageing, thus confirming the work of Musatti and Reggiori.² Similar treatment in nitrogen, or a vacuum, did not produce any such defects. Furthermore, evidence was obtained that, immediately after formation, the cracks contained hydrogen. Accordingly, the work reported in the present part* is mainly concerned with the role of hydrogen in the production of hair-line cracks.

COMPOSITION OF THE STEELS EMPLOYED.

Steel.	C, %.	Si, %.	Mn, %.	P, %.	S, %.	Ni, %.	Cr, %.	Other Elements, %.
F1	0.28	0.10	0.26	0.025	0.018	3.13	1.55	0.31 Mo
F2	0.61	0.20	0.80	0.04	0.04	—	—	—
F3	0.22	0.16	0.57	0.039	0.042	3.80	—	—
4831	0.33	0.22	0.57	0.027	0.034	3.18	0.70	0.23 Mo
C8	0.27	0.05	0.60	0.017	0.024	3.90	1.34	0.54 Mo
C9	0.30	0.25	0.61	0.035	0.030	4.04	1.35	0.51 Mo
C10	0.20	0.85	0.70	0.029	0.024	3.98	1.45	0.54 Mo
C11	0.34	1.88	0.70	0.012	0.028	3.90	1.44	0.54 Mo
F13	0.24	0.19	1.03	0.02	0.04	2.34	—	0.74 V
F23	0.33	0.06	0.60	0.012	0.035	4.04	—	0.30 Ta
F24	0.33	0.44	0.87	0.034	0.018	3.93	—	0.27 Ti
F26	0.61	0.21	0.37	0.024	0.011	—	—	—
S65	0.29	0.22	0.45	0.031	0.028	2.98	1.34	0.34 Mo

Some thirteen steels of varying composition were employed, the compositions of which are given above; these were given a standard hydrogen treatment, specimens, in the main, receiving 90 hours treatment in hydrogen at 1,200° C., followed by water-quenching; these were subsequently examined for cracks. Further steels were also examined to study the effect of carbon in the hair-line crack formation. These comprised five nickel-chromium-molybdenum steels with varying carbon contents. The steels were made in the high-frequency furnace and were forged to 1½ in. in diameter, each piece being about 18 in. long. The compositions were: chromium, 1.2–1.4%; nickel, 3.2–3.3%; molybdenum, 0.28–0.30%; manganese, 0.18–0.22%; and silicon, 0.23–0.42%; while the carbon contents were 0.08, 0.11, 0.20, 0.35 and 0.44% for D1, D2, D3, D4 and D5, respectively. The methods of examination adopted as standard consisted in deep-etching a complete longitudinal section and a half transverse section in boiling hydrochloric acid for 2 hours. The method showed up all the cracks which were revealed by the magnetic crack detector, and, in addition, frequently exposed narrower cracks which were too fine for detection by the magnetic method.

Both large and small test-pieces were used. The small specimens which can be used for extensive laboratory investigations must be quenched in order to ensure cracks, and this causes a characteristic distribution of cracks which is quite unlike that met with in industrial practice. The results obtained with large specimens justify the view that

cracks developed in smaller specimens after quenching are hair-line cracks, the quenching being necessary to retain sufficient hydrogen in the steel. The characteristic radial distribution of cracks in quenched specimens is attributed to residual stresses in the steel. The fact that residual stresses can affect the direction of cracks is borne out by those observed in industrial samples, in which the plane of the flakes is parallel to the direction of hot-rolling.

The results of the examination of specimens prove, in the authors' opinions, that hydrogen is the fundamental cause of hair-line cracks, and having reached this conclusion they endeavour to explain the mechanism by which hydrogen could be responsible. Of the many theories of hair-crack formation, the one which has attracted most attention is probably that due to Honda.³ According to this theory, on a falling temperature, atomic hydrogen diffuses into voids in the steel, is there converted to molecular hydrogen, and so builds up a pressure sufficient to disrupt the metal. In Part I it was shown that immediately after crack formation the cracks were filled with hydrogen. Furthermore, if it be assumed that the width of the completely decarburised layer, described in Part I, is six times the width of the crack, which is a conservative estimate, and taking the equilibrium methane content at 300° C. to be 14%, the value found to apply at low pressures, then the total pressure within the cracks at 300° C. must be of the order of 50 tons/sq. in. At first sight this would appear to be excellent confirmation of Honda's theory, but in his mathematical treatment of crack formation by hydrogen pressure, Honda arrives at the conclusion that, no matter what the conditions, cracks could not be formed above 580° C. nor below 200° C., whereas the experiments with two of the steels described in the present investigation proved conclusively that cracks are formed in quenched specimens at room temperature. Of greater importance is the fact that it is impossible to explain the sudden evolution of hydrogen associated with crack formation at room temperature in terms of Honda's pressure theory alone.

Since, in quenched specimens, a certain period must elapse at room temperature before the cracks are developed, and since their formation is closely associated with a sudden release of hydrogen, it seems probable that the hydrogen which is directly responsible for the formation of cracks must be held in a manner which differs from pure solid solution. If it be assumed that hydrogen treatment results in the presence of a hydrogen-rich constituent in steel, it is possible to explain all the experimental results described in this paper, and in so doing to obtain further details as to the nature of this hydrogen-rich constituent. In the first place, the hydrogen-rich constituent must be regarded as metastable at all temperatures, and, for a given steel, its stability will depend upon the amount of hydrogen in solid solution in the steel. During ageing, or on heating, the amount of hydrogen in solution is progressively diminished,

* Paper No. 6/1942 of the Alloy Steels Research Committee (submitted by the Hair-Line Crack Sub-Committee). Advance copy.

1 Andrew, Bose, Geach and Lee. *Jour. Iron and Steel Inst.*, 1942, No. II.

2 Musatti and Reggiori. *Revue de Metallurgie, Memoires*, 1933, vol. 32, p. 531.

3 Honda and Hironé. *Science Reports of the Tôhoku Imperial University*, 1936, vol. 25, Dec., pp. 713-723.

until a critical concentration is reached at which rapid breakdown of the hydrogen-rich constituent occurs. Some of the hydrogen thus released will diffuse into cavities or voids and there build up a disruptive pressure in the manner indicated by Honda, and the rest will escape from the specimen. The proportion of hydrogen escaping from the metal will depend upon the rate of diffusion, and will account for the sudden evolution on ageing and also for the lowest evolution peak on heating unaged specimens.

With specimens of a given steel of approximately constant hydrogen content, and with otherwise similar experimental conditions, the lowest evolution peak will occur at about the same temperature—for example, the 220° C. peak with 4S 11. In general, however, the rapid breakdown of the hydrogen-rich constituent and the temperature at which the lowest peak on the evolution curve occurs will depend upon (i) the rate of heating, (ii) the stability of the constituent, and (iii) the amount of hydrogen in solution in the steel. When the heating is slow the hydrogen concentration will be reduced to the critical value at a lower temperature, and rapid breakdown of the constituent and the formation of cracks will occur accordingly. Similarly, rapid heating will cause the cracks to form and the evolution peak to occur at a higher temperature. This is supported by the results obtained during the heat-treatment of hydrogen-treated and quenched specimens. The appearance of the cracks must be governed by the mechanical properties of the steel at the temperature of crack formation, and it was in fact found that the nature of the cracks depended upon the rate of reheating. If, in a normal low-alloy steel, the constituent decomposes at room temperature, when the steel is in a brittle state, the cracks are usually long and fine, whilst if the cracks are formed at a higher temperature at which the steel is relatively plastic, they appear wider and shorter, and in the limit are virtually "dots." On the other hand, when the carbon content is low, the steel will be relatively plastic, even in the quenched state, and the cracks are therefore short, although formed at room temperature.

The authors also discuss the effect of the stability of the hydrogen-rich constituent upon crack formation. It has already been assumed that the stability of the constituent is closely connected with the concentration of hydrogen in solid solution. If the constituent is unstable, little hydrogen will be lost from the specimen before rapid breakdown of the constituent occurs, and therefore there will be more hydrogen available for crack formation and the cracks will be more numerous, assuming other factors to remain constant. If the constituent is broken down by heating, instability will mean that the hydrogen is set free at a low temperature at which diffusion is slow, and from this point of view also more hydrogen will contribute to crack formation. On the other hand, if the constituent is relatively stable, which means that it will not break down at room temperature until more hydrogen has been lost, or on heating until a higher temperature has been reached, in both cases less hydrogen will be operative in a crack formation. In the extreme case it may even be possible, with a specimen containing a stable hydrogen-rich constituent, to reheat in such a manner as to prevent hair-line cracks. Thus, it is conceivable that by sufficiently rapid heating breakdown of the constituent might be postponed to a temperature range in which the rate of diffusion is so high that the hydrogen released by breakdown of the hydrogen-rich constituent can readily leave the metal, and no void would be able to retain hydrogen under pressure sufficient to disrupt the steel.

With the experimental conditions and the steels employed in this work the total hydrogen retained after quenching varies only within narrow limits, and the effect of hydrogen concentration upon the stability of the constituent is not marked. On the other hand it is clear that the composition of the steel is of major importance in determining the stability of the resulting hydrogen-rich constituent. Thus,

results obtained with the D series of steels can be explained only if the stability of the constituent increases with carbon content. In the first place, the temperature of the lowest peak on the evolution curve increases progressively from 50° C. for D 1, containing 0.08% carbon, to 315° C. for D 5, containing 0.44% carbon. Supporting evidence is afforded by results obtained during heat-treatment of the same series of steels. Thus, with the steel of lowest carbon content, heat-treatment produced no effect upon the number of cracks, because the constituent was very unstable, and in all cases cracks were formed at or near room temperature. With increasing carbon content the effect of heat-treatment upon hydrogen-treated and quenched specimens were more and more marked.

In general, the gas evolution at room temperature fitted in with these ideas of stability. When the incubation period was short—that is, the constituent was relatively unstable—the total amounts of hydrogen evolved were larger and more numerous cracks were observed. With the D steels the evolution of gas at room temperature fell with increasing carbon content, and this is probably to be attributed to two separate effects: First, the greater stability of the constituent, and secondly, the larger amounts of methane formed in steels of higher carbon content. The methane content of gas samples collected from the specimens was usually low, and can bear no direct relationship to the methane contained in the cracks, since methane, as such, cannot diffuse through the metal. The methane actually analysed was usually formed by reaction between evolved hydrogen and the carbon contained in the surface layers of the specimen, and this accounts for the remarkable constant methane percentages observed in the experiments with steel 4S 11. On the other hand, when the nitrogen content of the steel was high, as in the case of ammonia-soaked forged 4S 11 and hydrogen-treated cast 4S 11, some of the cracks extended to the surface. In cases like these the percentage of methane in the gas sample was high, even when the gas was evolved at room temperature, and this must be taken as evidence that the cracks contained considerable quantities of methane. Owing to the fact that hydrogen will diffuse to the surface of the cracks in the atomic state, and will therefore be intensely active, and because of the high pressures which must exist within the cracks, the formation of methane, even at room temperature, is not surprising. The top peak on the evolution curve obtained on heating has already been attributed to the breakdown of methane, but it is not possible, in the case of aged specimens, to say whether all this methane already existed in the cracks at room temperature, or whether it was formed during heating. In the specimens heated for evolution immediately after quenching, the methane, like the cracks, must have been formed during heating. As might be expected, with the D steels there was a general tendency for the magnitude of the methane peak to increase with the carbon content of the steel.

During the investigation of the effect of the soaking time in hydrogen upon crack formation in steel 4S 11, it was found that, although there was only a small difference in the total hydrogen content from the shortest to the longest time of soaking, nevertheless the number of cracks differed considerably. This suggested that the shorter the time of soaking, the less effective was the hydrogen in crack formation, a conclusion which is borne out to some extent by the results obtained on the tantalum steel. In this case the longer the period of soaking the less was the hydrogen evolved at room temperature per unit length of crack formed in the longitudinal section of a standard specimen.

It has been suggested that, with a given steel and a given hydrogen treatment, the hydrogen concentration must be reduced to a critical value before the rapid breakdown of the hydrogen-rich constituent can occur. While this suggestion is necessary in order to explain the results obtained, it is difficult to give direct experimental confirmation. Nevertheless, with the plain carbon steel F 26,

the same amount of hydrogen was evolved before the sudden evolution associated with crack formation, whether the specimen was aged at room temperature or was heated to 150° C. immediately after quenching.

It will be realised that many of the properties postulated above for the hydrogen-rich constituent are those actually observed for the white streaks which were such a prominent feature of the microstructure of hydrogen-treated and quenched steels. The white streaks disappear with time both at room temperature and on heating, and the intensity and sharpness of the streaks increase with the carbon content of the steel. In Part I it was stated that the microconstituent was austenitic in nature, and no result contradictory to this view has yet been obtained. Granted the austenitic nature of the white streaks and linking them with the hydrogen-rich constituent postulated above, it becomes possible to account for some of the effects of alloying elements upon hair-line crack formation. Thus, carbon or carbide-forming elements such as chromium or manganese would be expected to stabilise the constituent, whilst graphitising elements, such as nickel and silicon, should render it unstable.

It is not intended to suggest that each white streak observed in the microstructure would normally develop into a hair-line crack. The microconstituent probably serves only as a storage place from which hydrogen may subsequently be released, to form cracks by building up high pressures in voids. The positions of the cracks developed will be governed by the voids and other weaknesses existing in the steel, and stresses may play an important part.

As already shown, when the hydrogen-soaked specimen 4S 11C was air-cooled it lost very little hydrogen in the γ region, and this is probably due to the low rate of diffusion of hydrogen in γ -iron. On the other hand, the drop in hydrogen solubility at the γ - α change must have an important bearing on the formation of the constituent. All the results so far obtained suggest that, given an initially high hydrogen content in the steel, the hydrogen-rich constituent is formed whenever the specimen is cooled too rapidly through the γ - α change for the solubility/temperature curve to be followed. The critical rate of cooling will be governed by various factors, the most important being the size of specimen and the temperature of the change-point. The larger the specimen the greater is the distance through which hydrogen must diffuse, and therefore the slower is the rate of cooling necessary to avoid the retention of hydrogen. The higher the change-point the greater is the rate of diffusion, and therefore less time is required for the surplus hydrogen to diffuse out of the steel.

With the specimens employed in this work crack formation at room temperature was accompanied by the evolution of much of the hydrogen originally contained in the steel, and was followed by further gradual evolution. It might be supposed, therefore, that a method of avoiding hair-line cracks in the finished product in industry would be to expel the hydrogen by allowing hair-line cracks to develop, ageing and reforging. In many cases such a treatment would probably be successful, but there is the danger, particularly with steels of high-carbon content, that the methane stored in the cracks and unable to escape at low temperatures would, on reforging, break down and release sufficient hydrogen to saturate the steel once more, and so give rise to a new series of cracks on cooling.

Bearing the methane in mind, it is clear that any attempt to expel hydrogen by heat-treatment must be carried out at as high a temperature as is possible within the α range. Whilst a low-temperature treatment may be satisfactory for the removal of hydrogen as such, it would fail to overcome the trouble arising from methane.

Conclusions

The work described in this paper has led the authors to the following conclusions:—

1. Hydrogen is the fundamental cause of hair-line cracks.
2. The hydrogen which subsequently causes cracks is not in solid solution, but for a time is held in the form of a hydrogen-rich constituent which is formed on rapid cooling through the γ - α change.
3. Breakdown of the constituent releases hydrogen, some of which diffuses into voids and builds up a disruptive pressure.
4. In addition to hydrogen the cracks contain methane, even at room temperature, and the presence of this methane is the cause of some of the difficulties encountered in the industrial prevention of hair-line cracks.
5. The influence of composition on the susceptibility of a given steel to hair-line crack formation is explained by the effect of alloying elements upon the stability of the resulting hydrogen-rich constituent.
6. Once the constituent has been formed its breakdown at low temperatures must lead to hair-line crack formation. On the other hand, hair-line cracks will not result if breakdown of the constituent can be brought about at a sufficiently high temperature.

Distribution of Shear Stress in Spot Welds

It has been suggested by various authorities that porosity in spot welds, as long as it is confined to a small area in the centre of the spot, does not have any appreciable effect on shear strength. The distribution of shear stress has been found by photoelastic investigations to support this theory.

The theory has been tested and the investigation is described by Tylecote.* Tests were made on three sets of welds in 16 gauge aluminium-coated Duralumin in D.T.D. 390. Some of the welds in every set were drilled with $\frac{1}{16}$ in. and $\frac{3}{32}$ in. twist drills. The specimens were tested in a tensile testing machine.

In the "as welded" specimens, the apparent shear strength increased as the weld diameter decreased. The "actual" shear stresses did not follow any consistent rule, but the corresponding figures of each series were approximately inversely proportional to weld diameter, as was the case with the apparent shear stresses.

Drilling of a hole through the centre of the spot reduced the shear strength in all cases, although this decrease in the case of the largest weld for the $\frac{1}{16}$ in. hole was very small. The percentage reduction in area due to drilling out, in most cases approximately corresponded to the per cent. reduction in shear stress.

* R. F. Tylecote, *Inst. of Welding Quarterly Trans.*, Vol. 1, July, 1942, No. 3, pp. 143-144. (Abstract from *Light Metals Bulletin*, December 15, 1943.)

Errata

On page 10 of the November issue an abstract is given of a paper by Mr. John Rae, jun., on "The Use of Fired Small Arms Cartridge Cases in the Production of Some Alpha-Beta Extrusion Brasses." The original paper is published in the October issue of *The Journal of the Institute of Metals*, and the following footnote was inadvertently omitted from the abstract.

John Rae, jun., *J. Inst. Metals*, 1942, 68, 311.

On page 36 of the same issue the "Constitution of Alloys Bibliography," reviewed on that page, was compiled by Dr. J. L. Haughton.

On page 49 of the December issue the heading to Table IV should read "Commercial Magnesium Wrought Alloys"; while in the caption to Fig. 8 the description should be (A) JU 87 engine bearer, (B) Undercarriage mounting bracket, (C) Dornier 217 undercarriage leg mounting, (D) Tail-wheel fork and bracket, (E) Heinkel HE 111 undercarriage radius arm.

Second Report of the Moulding Materials Sub-Committee

Since the publication of the First Report of the above Sub-Committee, which is included in the Third Report of the Steel Castings Research Committee, 1938, of the Iron and Steel Institute, attention has been directed to the investigation of possible alternatives to bentonite for the bonding and revivifying of moulding and core sands. The results of these investigations are given in the present Report, abstracts from which are included in this review.*

THE fundamental investigation of the characteristics of bond clays and of the mechanism of bonding, which is in progress by the Moulding Materials Sub-Committee, has already confirmed the superior bonding of clays of the montmorillonite type. Apart from the fuller's earths the only clays occurring in Great Britain, so far found to be rich in minerals of the montmorillonite group, are those occurring in the London clay measures, but they also contain a high proportion of silicious silt which lowers their bonding power. The bond strength, the ratio of green strength to dry strength and the range of retention of green strength with increasing moisture content of clays, etc., containing montmorillonite clay substance has been shown to be almost directly as their montmorillonite content.

With the collaboration of the Fullers' Earth Union Ltd., selected and treated varieties of fuller's earth, occurring in Somerset and Surrey, to which the general designation Fulbond has been given, and which has bonding characteristics close to those of normal bentonites, have been developed. Following exhaustive laboratory tests and foundry trials, the attention of foundries was directed to this suitable alternative to bentonite; in most foundries a marked degree of success has attended its use, and bentonite has either been eliminated or its consumption very considerably reduced. A large tonnage of Fulbond is now being used in foundries and this usage is likely to continue even when bentonite is freely available again. To meet the needs of foundries requiring a bond with a rather greater moisture-holding capacity than Fulbond No. 1, Fulbond No. 3 has been developed, and this is also especially useful in foundries where the thorough milling which is desirable to develop the full bonding power of Fulbond No. 1 is not possible. Foundry experience has shown that the ramming, casting and stripping properties of the Fulbond mixtures are closely comparable to those of bentonite mixtures, and in reclamation plants the "life" of Fulbond is proving satisfactory. Fulbond can also be used satisfactorily as a suspensory agent in silica paint in place of bentonite.

A number of other substitutes for bentonite have been investigated in the laboratory and the foundry, but none of them appears to be so generally useful as a selected variety of Fulbond.

A considerable number of clay bonds have been investigated fully, and the trials show that some of them when used in proportions of 5-10% with a high-silica sand give satisfactory green strength but are lower in dry strength than normal Fulbond or bentonite mixtures. The clay-bonded sands have a greater hot strength than the Fulbond or bentonite mixtures, and in some branches of foundry work this is a definite advantage. Laboratory investigations and foundry trials indicate a useful field for mixtures of a good bond clay with Fulbond, the Fulbond addition improving the plasticity and dry strength without markedly reducing the hot strength. When mixtures of clay and Fulbond are used it is necessary that the mixing

shall be thorough. Where stocks of bentonite have been in existence attention has been directed to means of conserving them by the use of Fulbond-bentonite and bentonite-clay mixtures.

An investigation on the production of steel moulding sands by the thorough grinding and admixture of selected clays with selected sandstones is in progress. Some of the sandstones examined contain from 7 to 12% of partially weathered feldspathic matter, and these have been shown to be a useful base for steel moulding sands; with the incorporation of 10-20% of clay the product has good general properties and can be diluted with silica sands to provide a range of strength and permeability. Special attention is being given to the weathered sandstones, such as those of the Wolsingham district of County Durham which, because of their high content of "clay" from the decomposition of included feldspathic minerals, give, when thoroughly broken down by wet-grinding, a moulding sand which is satisfactory in general steel foundry use.

Experiments have been made with the addition of wetting agents to the water used in preparing moulding sands, but these additions do not appear to increase the rate of spread of the bond clay and have little effect on the strength of the moulding sand.

Investigations into the use of core binders have been made with particular reference to the possibility of effecting a reduction in the consumption of linseed oil and corn-starch products. It has been shown, for example, that in many cases up to one-half of the linseed oil in a core mixture can be replaced by Truline binder (a synthetic resinous material) without detriment to the strength and collapsibility of the core. Truline binder is particularly effective where reclaimed sands are used for core-making. Economies in the consumption of dextrin and other corn-starch products are of special importance, and attention is directed to the investigations which indicate the possibility of reducing the proportion of these materials in core mixtures by incorporating in the mixture a proportion of silica flour or a finely divided highly siliceous clay. One disadvantage of such mixtures is a reduction in permeability, but the trials which have been made indicate the possibility that undue importance has been attached to high permeability in cores. It has been shown in many instances that a reduction in the total quantity of core binders in a core sand does not result in any falling-off in performance.

As the quantity of sulphite lye available for use in foundries is decreasing, investigations have been made of possible alternatives which would have a similar behaviour in core mixtures. The use of "clay" binders in core mixtures has been examined, and the indications are that the incorporation of a proportion of a naturally bonded sand, a synthetic clay-bonded sand, bentonite, Fulbond or bond clay gives satisfactory results and renders possible an effective reduction in the proportion of organic binders. It must be borne in mind that highly colloidal bond clays, such as bentonite and Fulbond, tend to absorb an undue proportion of the organic bond, and that the

* Paper No. 3/1942 Steel Castings Research Committee (published Iron and Steel Inst.). Advance copy.

proportion of clay bond must be limited so as to avoid poor collapsibility of the cores after casting.

Owing to the necessity for increasing the production of silica sands and fine core sands, and to reduce the long-distance transport of sands, a large number of additional sources have been investigated fully. A number of these are now in use in foundries in the various steelmaking areas. These investigations are to be reported fully in a separate paper, but it is gratifying to note here that imported sands have, in the main, been satisfactorily replaced by home resources.

To provide information needed by the Foundry Practice Sub-Committee, investigations of the thermal expansion of sand mixtures containing clay, and of mixtures of low thermal conductivity suitable for use in certain types of feeder head, have been made.

Special attention is directed to the desirability of the calibration of pressure gauges on hydraulic machines for the measurement of dry strength. In other work on the testing of sands a new simple type of permeability apparatus has been developed, which gives accurate results for sands of both high and low permeability; a full account of this apparatus is given.

An investigation on the hot strength of moulding sands is in progress, and it seems likely that its results will provide data of definite value to foundries, especially when considered in conjunction with high-temperature sintering tests. Methods for measuring the plasticity of moulding and core sands and the surface characteristics of sands are also the subject of investigation.

The Sub-Committee have been able to render service to numerous steel foundries where troubles have arisen in the supply or use of moulding or core sands and they have collaborated with the British Cast Iron Research Association and the British Non-Ferrous Metals Research Association in matters of mutual interest. Much work has been done on behalf of the Foundry Bonding Materials Control of the Ministry of Supply.

British Moulding Sands

Extensive data is given in this Report obtained as a result of the examination of possible British alternatives to Belgian and French moulding sands. Results of the investigation of a number of British sands were published in the First Report of this Sub-Committee. Since then the work has been carried on continuously. Several additional deposits have been developed; others have been surveyed and representative samples of sand obtained from them. Observations on the deposits and the results of testing sand samples are given of moulding sands from the Raynham Estate, Fakenham, Norfolk; from Redhill, Surrey; from a quarry near Melksham, Wiltshire; I.M. Sand and "Serumite" bonding clay from Western Foundry Supplies, Ltd., Bournemouth; from Brookside Farm, Higher Kinnerton, near Chester; from the Durham area; Leighton Buzzard steel moulding sand No. 27; and from the Alderley Edge Red Moulding Sand Co. Ltd., Cheshire.

The Permeability of Moulding Sands.—The permeability of moulding sands is of direct importance in foundry work. For instance, the rate of drying of dry-sand moulds, under a given set of conditions, is governed mainly by the permeability of the sand; the strength of both green-sand and dry-sand moulds and the extent to which a core sand can accommodate the contraction of a casting during cooling are all closely related to permeability. Thus, the Sub-Committee directs particular attention to the determination of permeability and discusses two types of apparatus for carrying out tests.

One of these, the British Cast Iron Research Association air permeability apparatus, shown in Fig. 1, has several disadvantages. The chief of these is that the pressure in the air reservoir is not constant; on the contrary it depends on the permeability of the test-piece. Whether the pressure of the air passed through the test-piece is measured by a manometer attached to the pipe-line

between the reservoir and the test-piece holder or is connected separately to the holder, it does not record the pressure of the air in the reservoir. The air pressure in the reservoir is higher than the recorded pressure owing to the resistance of the pipe line; this resistance is variable depending on the rate of flow of the air through the pipe, and therefore on the permeability of the test-piece.

It has been the practice to add weights to the reservoir so that the manometer reading shall be constant at 10 cm. of water, but, if the manometer reading is to be constant the air pressure in the reservoir must be higher for test-pieces containing some sand mixtures than for test-pieces in other mixtures, hence the mass of air passed through the test-piece is varied according to the permeability of the test-piece.

To overcome this difficulty, a second type which is really a modified form of permeability apparatus was designed, as shown in Fig. 2. In this form, the reservoir floats on water and is maintained in an upright position by means of a small counterpoise. The outlet from the reservoir is made of steel pipe, having a bore of 2 in. and

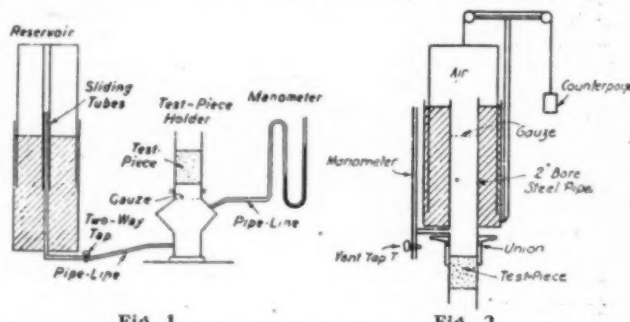


Fig. 1.

Fig. 2.

Fig. 1.—British Cast Iron Research Association air permeability test apparatus.

Fig. 2.—Modified permeability test apparatus.

a length of more than six diameters. A disc of wire gauze is fitted in the pipe at a distance of two diameters from the top. By this means the air flow is rendered uniform over the whole of the cross-section near the bottom of the pipe, where the pressure is measured. The test-piece is rammed in a short length of pipe of 2 in. bore and attached to the outlet pipe.

In operation, the lower end of the test-piece holder is closed by a glass plate coated with vaseline. The vent tap T is opened, the reservoir raised and the tap closed. The level of the reservoir is then observed to see that there are no leaks. Provided that there are none, the glass plate is slipped off, and the time for the passage of 1 litre of air and the manometer reading are noted. The pressure when the glass plate is in position is 7.35 cm.; this falls to 7.2 cm. when the plate is removed, and this value is independent of the permeability of the test-piece. Furthermore, if the empty test-piece holder is used, the reservoir discharges instantaneously on the removal of the glass plate. Thus, the resistances due to the pipe line, friction and viscosity are negligible.

A comparison was made between the permeability determinations by the British Cast Iron Research Association apparatus and by the modified apparatus the results of which are given, while a further series of tests were made in order to indicate some of the factors influencing the permeability of moulding sands, such as ramming density, moisture content and bond content, and nature of bond.

Thermal Expansion of Sand Mixtures Containing Clays.—Experiments were carried out to discover whether there was any important difference in the rate of expansion on heating and the final expansion reached when sand mixtures were made up with three different types of clay. Colbond, ball clay and bentonite were used, but although the expansion of the mixtures containing Colbond and ball

clay is shown to be somewhat greater than that of the mixture containing bentonite, the difference is not great, and it is doubtful whether the small differences shown would have any significant effect on the behaviour of sands containing the different clays in actual use in the foundry.

The Use of "Insulating" Sands.—In the course of one of their investigations the Foundry Practice Sub-Committee discovered that improved feeding in certain types of head resulted from the use of a head lining with a low thermal conductivity and a number of "insulating" mixtures have been examined and their conductivities tabulated. It is noteworthy that mixtures composed of silica sand, sawdust and clay, which gave the lowest conductivity, was subsequently found to give the most satisfactory results when used for lining feeder-heads.

Conclusion and Recommendations.—The Sub-Committee suggest that, in view of present transport difficulties, which are always liable to increase considerably during the winter months, foundries should carry out trials more particularly of sands which occur reasonably near at hand.

The point must be emphasised that many naturally bonded sands do not yield their full strength on milling unless the rolls are sufficiently heavy and the time of milling is sufficiently long. The weight of the rolls should be the maximum which can be used without actually crushing the sand grains. The time of milling should be sufficiently long to distribute the clay uniformly over all the sand grains present, including those of the silica sand which is frequently used to dilute a heavily bonded natural sand.

The use in lining feeder-heads of mixtures with a low thermal conductivity is decidedly advantageous as far as feeding is concerned, but some care is necessary to ensure that this material, containing a large percentage of sawdust, does not become mixed with the ordinary backing sand when knock-out sand is being recovered for re-use.

Clays

The works on clays is detailed in a section in which special attention is directed to the use of fuller's earth in steel foundries. The properties of domestic clays of this type come nearest to those of bentonite and a large number of steel foundries formerly using bentonite are now using fuller's earth instead with good results. One point to be remembered is that the foundry life of fuller's earth appears to be slightly less than that of bentonite. As, in any case, the clay content of mixtures using fuller's earth is higher than that of mixtures with similar strengths containing bentonite, it is very advisable to make sure, if recovery or reclamation of moulding sand is being carried out, that a sufficiently high proportion of old clay or old sand is removed and new clay added. Neglect of this precaution may lead to trouble in stripping or other defects on the surface of the castings.

This section also includes a report on clays other than fuller's earth in which results are given of investigations on a number of clays. Trials show that some of them, selected ball clays in particular, when used in proportions of 5-10% with a silica sand give satisfactory green strength, but are lower in dry strength than normal Fulbond and bentonite mixtures. The kaolinite-clay-bonded sands have a greater hot strength than the Fulbond or bentonite mixtures, and in some branches of foundry work this is a definite advantage.

The Sub-Committee state that the search for British clays which might prove of value for foundry purposes has shown that many such clays occur in quantity in various parts of the British Isles. Following on foundry trials, a number are now in regular use and are giving very good results. The clays differ considerably in the green and dry strengths that they give when milled with silica sand, and also in the ratio of dry strength to green strength. One of the most important points which has emerged during the trials is the great improvement in the properties of such mixtures that can be obtained by using more than

one clay in a moulding sand. By selecting suitable clays for such mixtures almost any green strength, dry strength or dry/green-strength ratio required in a foundry can be obtained.

During the preparation of moulding mixtures in which domestic clays act as binder, the importance of sufficiently heavy milling for a sufficiently long time cannot be over-emphasised. In a number of cases unsatisfactory foundry results have been obtained, owing entirely to the lack of appreciation of this point. It is probably even more essential when a mixture of clays is being used instead of a single clay.

Where new deposits of clay are being developed the bonding properties of these clays are often improved if they are allowed to weather, or are kept in a moist condition, for a few weeks before being used. If this has not been done by the suppliers it should be carried out at the foundry.

Core Compounds and Core Sand Mixtures

In the foundry, sand mixtures containing clay as the essential binding materials are usually termed moulding sands, whilst those containing organic binders are classed as core or oil sands. It will be appreciated however, that some moulds are regularly made in organically bonded sands and cores are made in clay-bonded sands, but this section is concerned primarily with organically bonded core sand mixtures. The main object of the Sub-Committee's consideration of this subject is to make the best possible use of the materials available for this purpose. In their opinion, in view of the shortage of materials ordinarily used for making core compounds, core sands consisting of silica sand and organic binders should not be used except when really necessary. Foundries using ready-made core compounds are recommended to try core-sand mixtures containing smaller proportions of core compounds than they have normally used. The arrangements for handling cores, both before and after baking, can frequently be improved without much difficulty, and the need for excessive strength in cores thus reduced. Core creams should be used instead of semi-solid compounds wherever possible. Foundries making up their core sands from dextrin, linseed oil and other core materials should also carry out experiments using reduced proportions of these materials, aiming especially at decreasing the proportion of dextrin in the mixtures.

Where cores are made in the same shop in a variety of sizes and shapes, they should be classified according to the green and dry strengths required, and different core compounds used for each class, small or simple-shaped cores naturally requiring a smaller proportion of core compound than others. To obtain the most economical results from organic binders, it is essential to weigh or measure out both the sand and the binder and to mill the mix thoroughly. To avoid waste, core sands should not be allowed to dry off on the bench; the easiest way to avoid this is to keep them covered up.

Association of Brass and Bronze Founders

At a recent meeting of the above Association, held in London, which was well attended and representative of the bronze and brass founders' industry as a whole, the Constitution of the Association was approved and adopted. Mr. Henry Bissell, of Messrs. J. Stone and Co., Ltd., was elected President for the ensuing year, and Mr. Geo. T. Hyslop, of the Phosphor Bronze Co., Ltd., was elected Vice-President. A General Council, comprising 16 members, was also elected, and also a Technical Committee of 12 members, exclusive of co-opted members from other organisations.

The secretaries are Heathcote and Coleman, 25, Bennett's Hill, Birmingham, 2, to whom all communications should be directed.

Tessellated Stresses

MOST of the physical properties of single crystals of many materials vary with the crystallographic direction in which the properties are measured, but a body which consists of an aggregate of crystals with random orientations may be considered to be a quasi-isotropic body. When such an aggregate is subjected to body stresses, or to a change of temperature, a system of self-compensated "tessellated stresses" becomes superimposed on the body stresses. The body stresses may be either an internal stress or the stress caused by an external load.

The magnitude of the orientation of the local tessellated stresses depend on the orientation of neighbouring crystals, and their investigation would involve questions of probability. They must lie between certain maximum and minimum values, depending on the space configuration of the physical properties of the crystal.

Tessellated stresses also develop in solids that consist of, or transform into, components which have different physical properties. Such stresses are called "structural tessellated stresses," to distinguish them from stresses due to anisotropy.

For bodies or portions of bodies which are quasi-isotropic from the structural point of view the exact treatment becomes a very simple question of statistical investigation. If, however, the components of the structural tessellation are individually anisotropic, the maximum possible fluctuation of stress due to crystal anisotropy for a particular component must be superimposed on the stress found from the structural investigation. In some combinations body stresses, too, must be superimposed.

If tessellated stresses develop uniformly over the whole of a body, no body-stress effect can be involved. If they are confined to portions of a body, and are accompanied by a non-negligible change in volume, the body, as a whole, is subjected to certain body stresses and strains.

In general, tessellated stresses form three-dimensional systems, and their investigation by direct measurement would involve great difficulties. For example, for stress measurements by X-ray diffraction methods it would be necessary for portions of the free surface of about 0.01 in. diameter to have nearly uniform values of tessellated stresses. Most metals are fine-grained, however, so that even structural types of tessellated stresses would not be revealed by X-ray diffraction. For this reason all the subsequent discussion in this paper by F. László* is based exclusively on the theory of elasticity and practical experiences. The tessellated stresses studied by the author were almost exclusively those of the structural type, including those due to difference of thermal expansion of the components. The author emphasises that numerous details connected with the problems discussed, and many problems relative to solids, including the possible tessellated stresses in individual crystals, seem to be worthy of future investigation.

* Iron and Steel Institute, December, 1942. Advance copy.

A Recording Dilatometer for Measuring Specimens

A dilatometer is described by L. R. Stanton* which produces a permanent record of the length changes of a specimen, with accuracy of 0.001 mm. The range over which measurement can be made extends to about 0.2 mm., the sensitivity being adjusted to suit any particular requirement. The measuring principle involves the tuning of an inductance about its resonant point by means of a small condenser actuated by the dilatometer, and particular care is taken to ensure stability of the apparatus over long periods.

* Paper No. 7/1942 of the Alloy Steels Research Committee (submitted by Professor F. C. Thompson), published by the Iron and Steel Institute, December, 1942. Advance copy.

The Properties of Wrought Aluminium Alloys

A Valuable Guide to the Economical Use of these Alloys

ALTHOUGH the oldest of the aluminium-rich alloys have been available for only a comparatively few years development has progressed very rapidly, and the engineering requirements which the materials can fulfil to-day are particularly wide. Some indication of the range of aluminium alloys now available in wrought forms is given in a booklet published by the Wrought Light Alloys Development Association, in which the principal characteristics of the wrought aluminium alloys are summarised in such a manner that they provide a valuable guide to the most economical employment of these alloys.

The wrought aluminium alloys are sub-divided into two main groups, namely, those which obtain their mechanical strength as the result of working only and those which are both worked and heat-treated, and current British Specifications are arranged in a chart which embraces these two groups. Further, the physical properties of representative alloys are given, and tensile properties required for these current specifications are summarised in several tables. Average hardness, shear and fatigue properties of representative alloys are also tabulated with commercially pure aluminium for comparison. Useful information is included on corrosion resistance, in which reference is made to "clad" sheet and strip, and to "contact corrosion"; machinability; cold-forming; jointing, including soldering and brazing, fusion welding, and resistance welding; and surface finishing. An interesting feature is a summary of recommendations of particular specifications for specific applications, which should prove exceedingly useful. The booklet carries an index for convenient reference.

This booklet is admirably prepared, and its 28 pages are full of essential information to all users and potential users of wrought aluminium alloys. It is the second of the Information Bulletins to be published by the Wrought Light Alloys Development Association, Union Chambers, 63, Temple Row, Birmingham, 2, and maintains the high standard which was set by the first issue. Copies may be obtained on application to the Association.

The Beaumont Proof Stress Indicator

MANY of those engaged in mechanical testing of metallic materials, particularly in relation to proof stress, will be familiar with the "Lindley" extensometer. It may not be so widely known, however, that in addition to designing his extensometer, Mr. Lindley was also largely responsible for the introduction of the four-point method of

proof stress determination, the formula $C = \frac{ad}{a+b}$ associated with this particular method being evolved by Mr. C. A. Crow, of Firth-Vickers Stainless Steels, Ltd. This ingenious method renders unnecessary the plotting of load-extension diagrams in connection with routine tests and enables determinations to be made quickly and accurately.

The value of this four-point method has been greatly enhanced by the introduction of the "Beaumont" proof-stress indicator, by means of which the actual mathematical solution from the formula is avoided. This instrument effects a considerable speeding up in the time necessary to arrive at the proof-stress value and avoids errors in calculation. This indicator is manufactured by J. E. Baty and Company, 39, Victoria Street, London, S.W. 1, and since many users of the four-point method are not familiar with its full scope the Company has published a manual which constitutes a useful guide to the more efficient use of this test and of the proof-stress indicator. Those interested should write to J. E. Baty and Co. for a copy of this manual.

War-Time Standardisation

The tremendous economic demands of our war effort have necessitated increased restriction on the production of consumer goods and the employment in war production of every machine available. In this way the national economy has been brought on to a total war basis. To facilitate production, the organisation and machinery of the British Standards Institution was made available to the Government, and Mr. C. le Maistre, C.B.E., Chairman of the Executive Committee of that Institution, discussed the contribution of standardisation in the war effort at a recent meeting of the North-East Coast Institution of Engineers and Shipbuilders, some of the main features of which are given in this article. Special attention is directed to his views on wrought steel rationalisation.

THE speeding-up of production has become the dominant factor in the national effort, and this is leading to more and more rationalisation and concentration of industry, which has become the order of the day. Seeing that results are required with the least possible delay, it will be understood that these drastic changes from peace-time to war-time production have to be undertaken on the basis of a short-term policy. Thus it is that maximum production coupled with the most economical use of materials, both raw and semi-finished, and the maximum expenditure of man-power have brought standardisation very much to the forefront.

Whilst the British Standards Institution has not undertaken work except on the basis of the fundamental principles which, since its inception in 1901, have guided its activities, it has maintained a procedure which, like the British Constitution, is unwritten, fluid and flexible. It is in large measure due to this flexible procedure that the organisation is not tied up with restrictive rules and regulations and so can make whatever changes become necessary in its procedure to meet any altered conditions as they occur.

This is well illustrated by the steps which were taken at the outbreak of war, when its organisation and machinery were offered to the Government to be used as the liaison with industry in the drafting of the many standard specifications which it was realised would quickly be required to meet the growing needs of war production. In order, however, to satisfy the requirements of the Government Departments as to speed and efficiency of our procedure, a number of small executive committees were at once appointed to review the position. There were at that time some 400 specifications in different stages of completion. A substantial measure of agreement was quickly reached as to which of all these could be left in abeyance and which should be completed with the least possible delay so as to make them available to industry at the earliest moment.

The Term "Standardisation"

Long experience has led to an enlarged conception of the term standardisation, and Mr. Maistre quoted from a recent memorandum by Mr. Percy Good, who has succeeded him as Director of the British Standards Institution. This gives a very clear exposition of what in this country is now included within this term, in regard to which there has been so much misunderstanding, and is as follows:—

The term *standardisation* covers a very wide field, but still is confined to one general idea—namely, the establishment of an agreed basis to serve as a reference for the assessment of the suitability of a product.

It takes two forms:—

- i. Functional.
- ii. Dimensional.

i. *Functional* standardisation is the establishment of the means of expressing quantitatively or qualitatively the fitness for purpose of materials, articles, components, machines, structures, etc., where the Imperial standards of weights and measures do not adequately do so. From this conception of functional standardisation, standards have taken the following forms:—

Terms and Definitions.—To secure uniformity and accuracy of description.

Quality and Performance.—To provide the measure whereby fitness for purpose can be expressed.

Methods of Test.—To ensure uniformity in the definition and properties by diminishing variations in test results due to differences in test procedure; also to encourage a more general adoption of testing by industry.

Methods of Use or Codes of Practice.—To define and guide the correct application of materials, articles, components, etc., and thus secure the adequacy of the result.

A great deal of work in the mechanical field, such as the B.S. Specifications covering the various types of boilers, and other pressure vessels, cranes, hydro-extractors, and so forth, may be said to be Codes, but not so much of practice as Codes of Construction.

ii. *Dimensional* standardisation to achieve simplification, unification and interchangeability. It may also be used as an indirect method of specifying quality.

War-time Standards

In the last war some of the greatest successes were due to standardisation, and some of the greatest tragedies were due to its absence. The production of tanks is an illustration of successful standardisation whereby the component parts manufactured in hundreds of factories thousands of miles away, when assembled in the British Isles, fitted perfectly. Another example is the use of standards in aircraft production. These were brought to a high pitch of excellence during the last war and are being kept fully up to date, thus maintaining the high quality of the materials employed in the manufacture of British aeroplanes.

Past experience has also shown that in many sections of industry it was necessary to limit the types, sizes, grades and qualities supplied in normal times. Even in those cases where industry was working exclusively to British standards it was necessary to introduce considerable rationalisation. While in war-time the fear of lessening output may engender a disinclination to undertake any broad scheme of standardisation, nevertheless, it is a fact that a considerable amount of useful standardisation has been and is being effected without in any way interfering with output. This must in due course show its effect by increasing production as a whole.

Since the outbreak of the war, in addition to urgent requirements of industry itself, though on a reduced scale, the B.S.I. has been very fully occupied in dealing with the many requests from various Government Departments for the drafting of what are termed War Emergency British Standards. The understanding is that when peace comes again these war emergency standards shall be subject to reconsideration with a view to their suitability, or otherwise, to peace-time requirements. The Institution has quickly organised the necessary consultation with industry and secured industry's support, the policy in certain cases where materials are in short supply and rationalisation is essential, having previously been determined by the

Government on the basis of priority. Some of these war emergency standards have been referred to in Orders in Council, or, in some cases, in a Direction issued by one or other of the Controls, which latter seems to serve the purpose equally well and to be forthcoming with less legal formalities in their preparation.

In the time at his disposal Mr. Maistre could only touch upon a few of the problems which have been carried out successfully under the aegis of the B.S.I. Of these, particular reference is made to packaging, wrought steels, nuts and bolts, tool manufacture, building materials, consumer commodity standards, air-raid precaution specifications, factory office systems, and standards in shipbuilding. The work reviewed certainly shows something of the extent to which standardisation on a national basis is assisting the war effort. And it has to be remembered, too, that the promulgation of these nationally agreed Specifications by the B.S.I. carries with it a very considerable measure of co-ordination between Government requirements and industrial possibilities, as well as the prevention of much overlapping of effort. The work on the standardisation of wrought steels may here be taken as an example of the efforts in this direction.

Wrought Steels

During the two or three years which preceded the outbreak of war certain efforts had been made to co-ordinate the steel specifications for the automobile and aircraft industries, but while some progress was made, the B.S.I. found it impossible to bring this to finality. War conditions emphasised the necessity for rationalising steel specifications with the first objective of reducing the number and at the same time providing a schedule of special and alloy steels covering the whole of the requirements of the fighting services and also for general engineering. This rationalisation was undertaken by what is known as the Technical Advisory Committee under the chairmanship of Dr. W. H. Hatfield, F.R.S. The Committee works under the Steel Control of the Ministry of Supply, and is composed of steel-makers, representatives of the Services, and the B.S.I., working in consultation with important consumers. This Committee placed its services unreservedly at the disposal of the B.S.I. and has acted in an advisory capacity in the preparation of War Emergency British Standard Specifications in order to give effect to its recommendations for special and alloy steels. This British Standard Schedule of specifications (B.S. 970: 1941) comprised a series of 58 wrought and alloy steels known as the "En series," and was first published in July, 1941. The range of steels was considered by the T.A.C. to be adequate as covering all the general engineering requirements of industry. It represented the analysis by that Committee of over 2,000 specifications, a work of considerable magnitude. The specifications were made as informative as possible, and data were given regarding "mass effect" relating to each of the types of steels dealt with.

This rationalisation of steel specifications was in the early part of 1942 taken a step further and given practical effect by a Direction issued by the Iron and Steel Control, stating that for general engineering purposes all steels must comply with a reduced range of 44 steels selected from B.S. 970 and the B.S.I. was requested by the Iron and Steel Control to circulate a memorandum to industry indicating the 44 steels in detail. This memorandum was published as B.S. 970A.

When B.S. 970 was issued it was fully realised that it would be necessary at an early date to review the position in order to incorporate the modifications found to be required in the practical working of this En series. The revision was issued in November last.

Complementary to B.S. 970 a companion document prepared by the T.A.C. was issued by the B.S.I. giving information regarding the use of the various steels and their classification. This rationalisation represents one of the

most important pieces of work which has come within the aegis of the B.S.I. since the war.

The desire of the Government Departments that narrower ranges of composition should be specified so as to make it possible for all steelmakers to deliver to a common stock and for users to draw from these stocks without regard to individual casts or suppliers, and to obtain the desired properties by using standardised heat-treatment, is evidenced by the issue, again by the B.S.I., of a Services' Schedule of Carbon and Alloy Steels for Armaments and Vehicles, known by the reference No. BS/STA. 5. It is essentially an explanatory schedule of requirements based on the recent revision of the British Standard steel specifications of the En series. It also takes into account the Direction of the Controller which limits the available types of alloy steels and enforces the economical use of alloying elements. This Services' Schedule has been drawn up by a conference of technical representatives of the various Government Departments in collaboration with the Superintendent, Technical Applications of Metals, of the Ministry of Supply. It represents a fusion of requirements for most general purposes of the smallest possible number of essential steels, including carbon and alloy types.

The Conference kept in mind the widely distributed nature of the engineering industry and the introduction of many new works as sub-contractors, the difficulty of maintaining the necessary degree of uniformity of individual parts and the need for simplification of the procedure for ordering material both by contractors for their own use and by Service departments for stock or free issue.

The principle of the adoption of common requirements for steels has been welcomed generally by user departments and contractors. Of course, some compromise within the large variety of pre-existing individual requirements has been essential, but this has been achieved without any great difficulty.

In drawing up this Schedule of Service steels for armament and vehicle manufacture, the Conference has kept in the closest touch with the T.A.C., and the document, or schedule, was looked upon as a contribution to the 1942 revision of B.S. 970. The hope is that the Service Schedule will materially assist production in general by ensuring increased availability and reasonable uniformity of the steels and of their response to heat-treatment. All the steels of the Services' Schedule are permitted steels within the scope of the Direction of the Iron and Steel Control.

It will thus be seen that little by little the views of the metallurgists who produce and the engineers who use the steels are coming closer together, and this is bound to have the effect ultimately of bringing about general agreement on a single series of rationalised steels.

In his conclusion, Mr. Maistre stated that, in normal times, the British Government, while actively associating itself with the preparation of British Standard Specifications and encouraging their use, has not as a general policy demanded their preparation. This demand has usually come from industry itself. War-time production, however, has shown that with the wide control of industry, the Government has found it necessary to take a much greater interest in the preparation of these national standards than was formerly the case.

Control of Magnesium

The Ministry of Aircraft Production has made the Control of Magnesium (No. 4) Order, 1942, which came into force on December 30, 1942. This order codifies the Control of Magnesium Orders (Nos. 1-3) and increases the price of D.T.D. 325, thus standardising the price of all unfabricated magnesium and magnesium alloys. It also reduces the maximum price of magnesium powder to 4s. per lb. for all grades, and specifies controlled prices of magnesium billets and rolling slabs. Copies of the new order may be obtained from H.M. Stationery Office, or from any bookseller.

Internal Stress of Metals

By C. A. Wilkins

Non-destructive testing is applied in practice to assess the value of a particular component for many purposes. Such a method of testing has not yet been successfully applied to determine the internal stress which may be present in a component. Some aspects of internal stress in metals are discussed, and the author suggests that tests might be based on accurate e.m.f. measurements or on the magnetic permeability of the metals.

IN these enlightened days when non-destructive tests for all purposes are gradually being perfected, when the Magnaflux crack detector, radiography, X-ray crystal analysis and spectrographic analysis have become everyday routine tests, it is becoming increasingly essential that some form of non-destructive test should be evolved for the measurement in a simple and straightforward manner of the internal stresses in metals.

A non-destructive test may be defined as a means of proving some particular quality of an article without impairing its adequacy for the service for which it is intended. Although the results of many non-destructive tests are capable of precise interpretation in general, the qualities which they are designed to prove can only be assessed by inference, whereas the destructive test gives a positive indication of the ultimate resistance of an article to the testing conditions imposed upon it.

The internal stress of a metal is a phenomenon of importance found within the elastic range of metals existing as a system of static forces in equilibrium, the sum total of the compressive forces being equal to the sum total of the tensional forces. When the equilibrium of such a system is upset we get distortion, warping and cracking as the residual stresses readjust themselves to maintain equilibrium. These stresses may be developed by plastic deformation, by temperature gradients, and by volume changes resulting from constitutional transformations.

In castings the stresses are chiefly induced by the liquid solid shrinkage effect and subsequent thermal stresses, the manner in which they are cooled affecting their behaviour, because if the relative rates of cooling of the thick and thin sections are not equalised, stresses may be set up in the castings sufficiently high to cause cracking; for example, curved S-shaped spokes are now used in cast-iron pulleys to accommodate internal stress after it was found that straight spokes fractured.

Some form of heat-treatment to remove stresses in castings has generally to be carried out, especially in castings of an intricate design. In steel castings it is general to normalise in the range of 850°–950° C., and for brass 600°–700° C.; in both cases phase changes taking place, causing recrystallisation. In light alloys, however, for example, aluminium alloys, it is sufficient to stress relieve at 250° C.

Thermal stresses due to differential cooling are set up in castings on cooling, or in the heat-treatment of the part. The mechanism of such stresses is shown in Fig. 1.

A specimen, say in the case of steel, is quenched from above its upper critical point. In cooling, the outer skin cools faster and contracts on to the central hot mass. This stress in the outer skin is so great that the outer skin is deformed beyond its elastic limit—i.e., permanently deformed. As the inside cools down more slowly it contracts and tries to make the outer skin contract as well: but having once been permanently deformed and the temperature being lower so that the elastic limit has increased, the outer skin is put into a state of compression and equilibrium is set up between the compressive stresses in outer skin and tensional stresses in centre. The effect of these stresses is generally brought out in distortion of the

part, distortion being especially excessive if the part is not symmetrical.

Similarly, after plastic deformation a material may be left in a state of stress, the intensity of which varies from place to place. This can be illustrated by examining the

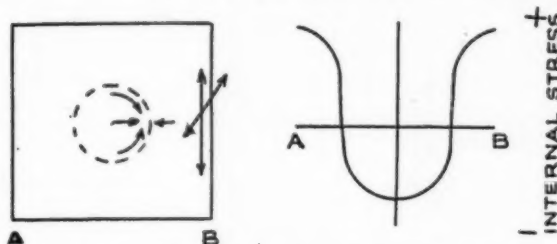


Fig. 1.—Thermal stresses due to differential cooling.

internal stresses set up by cold working a bar—i.e., by bending a bar, as in Fig. 2.

The bar, unbent, is relatively free from internal stress. The bar is bent, the skin on the outside bend of the bar is put into tension, while skin on inside of bend is in compression. When force released there is a recovery within the metal, and the skin on outside of bend is now put into compression and skin on inside of bend is put into tension.

Many examples can be given of excessive internal stress causing failures, but one of the most interesting is that which occurs in brass tubes, known as season cracking, which is liable to occur when they are used in the cold-worked condition. Failure takes place when the internally

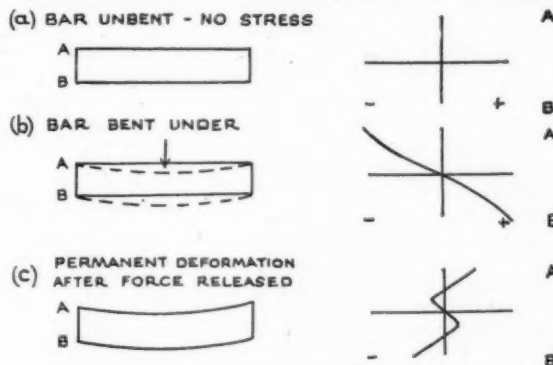


Fig. 2.—Internal stress in cold-worked bar.

stressed part is subjected to a mild corrosive medium—e.g., sea-water or industrial atmosphere. A characteristic of this failure is that the cracks pass around the grain boundaries, and the tensile stresses at skin cause the fractured surfaces to separate to a great extent. Internal stresses in brass which exhibited season cracking have been found as high as 16 tons/sq. in. tensional at surface, and 11.5 tons/sq. in. in compression at centre.

Other instances of failure due to cold work setting up internal stresses is that of forgings finishing at too low a temperature, resulting in severe strain hardening, causing

bursting, or the intercrystalline cracking, of boiler-plates round punched rivet holes. This latter effect, however, is probably due to the combined effects of internal stress, caustic alkalis in the water, and differential potentials set up between the plate and the rivet.

There are several methods of measuring or indicating the presence of internal stress in metals.

Lacquer Coat Method

In this method the specimen is coated with a special stress-coat lacquer and allowed to dry. The specimen is then carefully stressed, special care being taken in examining the specimen during application of load to ensure the detection of the first signs of cracking of lacquer. The load at which stress cracks develop is noted, and also the load when full stress crack pattern is obtained. In Fig. 3 a test-piece coated with lacquer and stretched illustrates a full stress-coat pattern, while Fig. 4 shows a stress-coat diagram of an aluminium piston.



Fig. 3.—Stress coat pattern on test-piece after application of load.



Fig. 4.—Stress coat diagram of aluminium pistons.

Comparative results can be obtained by machining specimens to certain shape and measuring equivalent distortion. This is particularly helpful in heat-treatment where specimens are machined in circular shape with a hole bored in centre and a notch cut from outside to centre. Distortion can be calculated by measuring the amount the notch opens or closes.

A common method of determination depends upon mechanically removing parts of the body, which disturbs the stress equilibrium and results in deformation of the remaining metal. Measurements of the deformation permit the estimation of the internal stresses in the portion removed. The latest methods devised by Kempf, Hopkins and Ivanso¹ are based on work of Howard² and Heyn,³ and consist of turning off layers from cylinders of the material under test, so that their final appearance resembles that shown in Fig. 5, and measuring the deformation after turning off each layer.

The cuts are made over L^1 , and the stress changes due to the cuts are measured over L^2 . With each cut the stress in each layer is removed with it, hence the remaining stresses in the bar redistribute themselves to attain an equilibrium and a length change of the bar results.

By the application of Heyn's formula, the stress in each machined layer can be calculated and the actual stress in n^{th} layer found.

$$S_n = \frac{E}{L} \frac{d_n^2 (L_n - L_0) - d_n - 1^2 (L_{n-1} - L_0)}{2240 (d_n - 1^2 - d_0^2)}$$

Where S_n = stress in n^{th} layer in tons per square inch; E = modulus of elasticity; L = length turned down; d_n = diameter of turned down part after n^{th} cut; d_{n-1} = diameter of turned down part after $n-1$ cut; L_0 = initial length of cylinder; L_n = length of bar after n^{th} cut; L_{n-1} = length of bar after $n-1$ cut.

To illustrate the distribution of stresses in each specimen the average stress in each layer can be plotted against one-half cross-sectional area of the machined specimen. This is illustrated in a later portion of the paper.

Stress distribution in metals subject to severe stress in service is now being extensively examined by means of photoelasticity. This is generally carried out by fabricating a medial section of the part to be examined from some of the photoelastic materials, like celluloid or bakelite, in sheet form and applying to the part similar stresses to those it would receive in service. The resulting stress lines can be examined by means of polarised light through a suitable polariser.

The X-ray method developed in recent years has been of considerable value in regard to the measurement of surface stresses. Wever and Möller⁴ have carried out X-ray measurements of the surface stresses in quenched and turned steel shafts. As a result of the turning operations additional stresses, amounting to approximately 40 kg./sq. cm., were set up in the surface layers. These additional stresses extended to a depth of 0.2 mm.; at a depth of 0.1 mm.

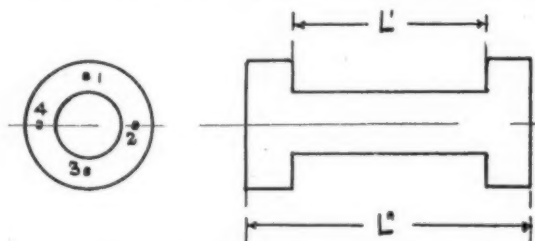


Fig. 5.—Diagram of final shape of specimen for measurement of internal stress.

they had decreased to about one-half. Slowly cooled almost stress-free shafts behaved otherwise on turning, either no stresses being set up or very small additional stresses which extended to a depth of approximately 0.2 mm. This disturbance of the surface layers, however, can be easily removed by etching, this etching, of course, being purely of research importance, because the accuracy at which shafts are machined will not permit of removal of such a substantial amount of material after machining.

As has been previously stated, internal stresses of large magnitude can be set up in metals during heat-treatment processes. These stresses, however, can be accentuated or decreased by various factors—for example, machining conditions, or the design or shape of the part being treated.

In the first case, when gears which have been hot upset from a nickel-chromium steel are quenched in oil from a hardening heat, those which have not been carefully handled during machining operations are liable to distort as much as 0.030 in. out of truth. The lack of care in machining might arise only for example in the "chucking" of the part. Gears which have been carefully handled, in prior machining, scarcely show any distortion—distortion being only in the region of 0.005 in. after quenching. Ruttman⁵ has shown by Heyn's method of stress measurement that on specimens similarly heat-treated, both compressive and tensile self-stresses can arise in the skin layer according to method of prior machining. In general, the compressive stresses were set up by slow cutting with good cooling, similar to those caused by surface pressure as a result of surface deformation. By rapid cuts and no cooling, and by grinding, tensile skin stresses, i.e., thermal stresses due to local heating, were produced. Austin,⁶ also using Heyn's method, has shown by tests on nickel-chromium steels the effect of water and oil quenching, and the effect of oil quenching and tempering on the internal

¹ "Internal Stresses in Quenched Aluminium and Some Aluminium Alloys." L. W. Kempf, H. L. Hopkins, E. U. Evanson. A.I.M.E. Technical Publication No. 635.

² "Tests on Hot-rolled Bars, Tests on Metallurgy." J. E. Howard. Watertown Arsenal, 265, 1893.

³ "Internal Stresses in Cold Wrought Metals and Some Troubles Caused Thereby." E. Heyn. *Journal of Institute of Metals*, 1914, 12/3/37.

⁴ "X-ray Stress Measurements on Quenched Steel Shafts." Wever and Möller. *Mitteilungen aus dem Kaiser Wilhelm Institut für Eisenforschung*, 1936, Vol. 18, No. 3.

⁵ "Machining Stresses." W. Ruttman. *Technische Mitteilungen Krupp*, 1936, Vol. 4, June.

⁶ "Stress in Steel." Austin. *Journal of West of Scotland Iron and Steel Institute*.

stress of the steel. He found the stresses on specimens oil quenched from 850° C. to be 42 tons/sq. in. compressive at edge and 26 tons/sq. in. tensional at centre, and that greater stresses remained after quenching from low-tempering temperatures than after hardening. He also found that re-tempering between 300° C. and 400° C. reduces the stresses slightly but by no means completely, and that for complete removal of the stresses a prolonged heating at 550° C. was necessary.

Design or shape of a part which is to have a heat-treatment performed on it is extremely important because of the dimensional changes which take place during heat-treatment. These dimensional changes depend on a number of factors; for example, in forgings, the expansion due to the formation of the martensite and the contraction due to the hot upsetting are probably of the greatest importance on quenching, but the shape of the part and the conditions during heating and cooling all tend to modify or influence the net result—hence the importance of the relationship of design to heat-treatment—i.e., the design as it affects the heat-treating operations and through the heat-treatment the serviceability of the finished part.

In this respect we have seen how internal stress is developed during quenching by reason of differential cooling, this differential cooling (temperature gradient) being largely a function of shape and size of part being quenched. Therefore one of the basic principles of good design is to plan shapes which will avoid marked changes in temperature between adjacent sections throughout the cooling cycle. Errors in design react further than merely affecting the internal stresses during quenching; a sharp angle serves to concentrate the stresses of service, and the design of that part may be entirely responsible for concentrating the service stresses at a point already weakened by internal stress produced during quenching, resulting in failure of the part.

For a number of years, due to the ever-increasing use of aluminium alloys for highly stressed parts, considerable work has been carried out on the determination of the internal stress set up in these alloys during manufacture and heat-treatment. Kempf, Hopkins and Ivanso show that considerable internal stress is set up in these alloys by quenching in different media from the solution treatment temperature (Fig. 6).

The stresses, after quenching in cold water, were found to be of the order of 7–10 tons/sq. in. The magnitude of the stresses induced by heat-treatment were influenced by the mechanical and physical properties of the alloys, the rate of cooling, and the volume and geometry of the specimen. Stresses in simple shapes were compressional at the surface and tensional at the centre of the specimens. To relieve internal stresses in these alloys in a relatively short period, it was found necessary to heat the parts above 300° C., and even at 300° C. several hundred hours were necessary for complete removal.

The graph shown in Fig. 7 illustrates the reduction of internal stress with rise in the stress-relieving temperature. Specimens were soaked for 2 hours at each temperature.

It was also found that the effect of cold work could alter the equilibrium of stresses induced by quenching, although internal stress does not appear to be related to the age-hardening process. Dehlinger⁷ having observed in the case of cold-hardening of aluminium copper alloys that the increase in hardening sets in without a basic alteration of the lattice, the material in solution being precipitated and forming complexes within the basic lattice. This complex is modified if a higher annealing temperature of about 130° C. is applied, when it gives way to the segregation visible under the microscope. This phenomenon was explained as being thermo-dynamic in origin. Changes however in internal stress are frequently associated with changes in inter-atomic spacing—hence, even stress changes

can be considered as due to changes in structure if we regard inter-atomic spacing as one of the elements of structure.

With increasing demands for more accuracy in machining of parts, and for uniform properties throughout these parts, the importance of internal stress has been revealed, and attempts made by industry to eliminate or control these stresses. There has been, therefore, numerous investigations with the object of developing a test to detect the presence of these residual stresses with or without destroying the part under test. The most important and accurate so far is that developed by Heyn's, which is based on the fundamental phenomenon that the removal of a part of a stressed body, usually by machining, causes both the cutout piece and the remainder to suffer elastic strain. This method, however, is a destructive one, and internal stress cannot be measured by this means unless the part is destroyed.

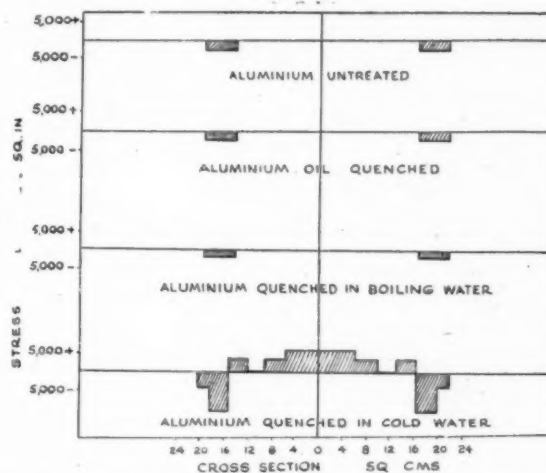


Fig. 6.—Stress diagram of aluminium after quenching in various media.

A sensitive non-destructive test has so far not been found, although recently non-destructive X-ray stress measuring methods have been introduced, but with mixed success up to the present. The author's suggestions are that tests might possibly be based on either accurate *e.m.f.* measurements, or on the magnetic permeability of the metals.

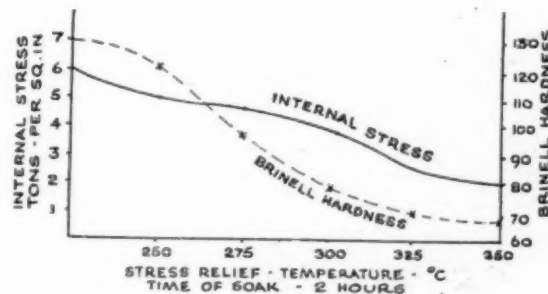


Fig. 7.—Graph showing reduction in internal stress with rise in stress-relieving temperature.

The *e.m.f.* measurement method might possibly be carried out in the following manner. The part under test to be the electrode of a cell, the electrolyte of which is a dilute solution of a salt which has no harmful effect on the metal, and the other electrode a standard one. By this means *e.m.f.* values could be found for all types of metals under various conditions, stress relieved, highly stressed, and the value obtained from the part under test checked against these standard values, thus giving the relative amount of internal stress present in the part.

(Continued at foot of page 120.)

⁷ "The Mechanism of Segregations and Transformations." U. Dehlinger, *Archiv. für das Eisenhüttenwesen*, 1936, Vol. 10, September.

The Chemical and Physico-Chemical Analysis of Iron and Steel

Twelve Years' Advancement

By E. C. Pigott

Books in English on the Analysis of Iron and Steel and Related Materials—Published since 1930.

IRON AND STEEL.

AMERICAN SOCIETY FOR TESTING MATERIALS.

"A.S.T.M. Methods of Chemical Analysis of Metals: Analytical Procedures for Ferrous and Non-ferrous Metals, Spectrochemical Analysis Methods." 1939. 2nd ed. (257 pp.). A.S.T.M.

Although the methods chosen are provided for referee analysis, they are not intended to preclude the use of other accurate procedures. In the 54-page section on ferrous metals, a description of the sampling of cast, rolled and forged products precedes the actual methods of analysis, of which those for C, Mn, Si, S, and P are described for carbon steels, with modifications for irons and alloy steels, whilst those for Cu, Ni, Cr, V, Mo, W, Co, Ti, and Zr are presented for steels containing alloying amounts of the respective elements, with modifications for irons and carbon steels. The methods are extremely reliable without being elaborate or lengthy, and all are well established. Knowles' (1932) benzoin oxime process probably being the most recent. Other sections deal in detail with the analysis of ferro-alloys and non-ferrous metals.

BRITISH CAST IRON RESEARCH ASSOCIATION.

"The Sampling and Chemical Analysis of Cast Ferrous Metals." E. Taylor-Austin. 1941. 3rd ed. (140 pp.)

A condensed account of sampling and general bench technique precedes a description of the most suitable methods for plain and alloy irons and ferro-alloys. Its author's own valuable processes are included, and those methods originally designed for steel have been adapted with the greatest care. Some 23 elements are considered, the selected processes being intended primarily for acceptance tests. The value of this important volume is enhanced by reference to the theoretical structure of the various methods.

GREGORY, E., and W. W. STEVENSON.

"Chemical Analysis of Metals and Alloys." 1937. (375 pp.) Blackie.

In the preliminary chapters the fundamental principles of physical and analytical chemistry are presented in an informative and lucid manner. The description of quantitative methods for 26 constituents of iron and steel is particularly concise and free from matter irrelevant to actual procedure, the classical methods selected serving for a wide range of materials. This section, comprising 92 pages, includes a well-illustrated and detailed account of the determination of gases and inclusions.

JOHNSON, C. M.

"Rapid Methods for the Chemical Analysis of Special Steels, Steel-making Alloys, Their Ores, Graphites and Bearing Metals." 1930. 4th ed. (729 pp.) Chapman and Hall.

The somewhat haphazard arrangement in the previous (1920) edition has not been adjusted, and in place of needed revision an appendix of 176 pages has been introduced. Despite the immense progress made since publication, the volume remains valuable in regard to analytical schemes for miscellaneous materials, whilst original modifications are to be found in the methods for special steels. Little experience is expected of the reader, the various operational details being described at some length. Diagrams and photographs of equipment are plentiful, but the text contains few references to sources.

LUNDELL, G. E. F., et al.

"Chemical Analysis of Iron and Steel," by G. E. F. Lundell, J. I. Hoffman, and H. A. Bright. 1931. Chapman and Hall. (641 pp.)

A very popular standard work now in need of revision, certain methods having been simplified since publication. The entire

subject is treated exhaustively with some reference to fundamental theory and adequate consideration of the influence of accompanying elements. The analysis of related materials is discussed in equal detail and the whole text is particularly well documented.

PIGOTT, E. C.

"The Chemical Analysis of Ferrous Alloys and Foundry Materials." 1942. (362 pp.) Chapman and Hall.

Amongst the 28 elements dealt with in detail are those of most recent application. Many modern methods, which hitherto have appeared only in journals, have been developed and adapted, whilst other processes have been simplified and adjusted to ensure specificity. Advantageous reactions with organic reagents have been fully exploited. Information on the extraction, general and chemical properties and influence of each element precedes the actual methods of determination, which are supplemented by a thorough account of their evolution and underlying theory. Special attention is paid to the modern chemistry of the various constituents. The consideration given throughout to rapid and reliable routine practice is noteworthy, specially rapid methods having been selected for the analysis of bath-samples. General theoretical principles, as now accepted, are conveniently presented in glossary form. The index, amounting to 14 pages, covers both practice and theory in detail.

UNITED STATES STEEL CORPORATION.

"Sampling and Analysis of Carbon and Alloy Steels." 1938. (356 pp.) Carnegie Steel Co.

The various confirmed methods described for each element represent the best in modern practice, their relative merits being left to the decision of the reader. Sampling of materials is considered in useful detail, the whole volume being essentially practical, with few references to analytical theory. Available processes for estimating oxygen and hydrogen are discussed, but are regarded as requiring further development before being recommendable as practical methods.

UNITED STATES STEEL CORPORATION.

"Methods of Chemists of Subsidiary Companies of U.S. Steel Corporation for Sampling and Analysis of Pig Iron." 1934. 3rd ed. (100 pp.) Carnegie Steel Co.

A well-illustrated section of 23 pages on the sampling of both molten and cast metal precedes the main portion devoted to routine analytical methods for the principal elements and referee procedures for C, Si, S, P, Mn, Fe, Ti, Cu, Mo, Ni, Cr, V, As, and Al. Though based on a vast amount of information contributed by numerous companies, the selected methods are presented in a clear and concise form adapted to serve even the less-experienced analyst. Due attention having been paid to the usual sources of error, a valuable combination of accuracy and speed has been attained. Principles of the methods are treated but briefly, and few references are given. The publisher's admirable presentation of the volume is a notable feature.

UNITED STEEL COMPANIES, LTD.

"Standard Methods of Analysis of Iron, Steel, and Ferro-alloys." 1936. 2nd ed. 81 pp. United Steel Companies.

The essence of this useful bench-companion is brevity, the text being free from diagrams and consisting solely of procedure with no reference to either theory or sources. The methods have been selected in the light of analytical research conducted by the subsidiary companies and the effect of the common interfering elements has been considered throughout. Standard procedures are described for C, Si, Mn, S, P, As, Ni, Cr, V, Mo, Co, W, Cu, Ti, Al, and Zr in steel; for Si, Mn, S, P, As, and Cr in cast iron; for Si, Mn, Cr, V, Mo, Ti, and W in their ferro-alloys; and for Al, Si, and Ti in alumin.

RELATED MATERIALS.

- CLOWES, F., and J. B. COLEMAN.
"Quantitative Chemical Analysis." An intermediate textbook, ed. by D. Stockdale and J. Dexter. 1938. 14th ed. Churchill.
- HILLS, F. G.
"The Technical Analysis of Ores and Metallurgical Products." 1939. 2nd ed. Spon.
- KOLTHOFF, I. M., and E. B. SANDELL.
"Textbook of Quantitative Inorganic Analysis." 1937. Macmillan.
- LOW, A. H.
"Technical Methods of Ore Analysis: for Chemists and Colleges." Ed. by A. J. Weinig and W. P. Schoder. 1939. 11th ed. Chapman and Hall.
- MELLOR, J. W., and H. V. THOMPSON.
"A Treatise on Quantitative Inorganic Analysis: with Special Reference to the Analysis of Clays, Silicates, and Related Minerals." 1938. 2nd ed. Griffin.

- SCHOELLER, W. R.
"The Analytical Chemistry of Tantalum and Niobium." 1937. Chapman and Hall.
- SCHOELLER, W. R., and POWELL, A. R.
"The Analysis of Minerals and Ores of the Rarer Elements." (1940). 2nd ed. Griffin.
- SCOTT, W. W. and N. H. FURMAN, eds.
"Standard Methods of Chemical Analysis." 1939. 2 vols. 5th ed. Tech. Press.
- SNELL, F. D. and C. T.
"Colorimetric Methods of Analysis." 1936. 2nd ed. 2 vols.
- SUTTON, F.
"A Systematic Handbook of Volumetric Analysis." 1935. 12th ed.
- TREADWELL, F. P., and W. T. HALL.
"Analytical Chemistry." 1935-37. 2 vols. Chapman and Hall.

The War and Patents Relating to Zinc

By S. T. Madeley

The effect of the last Great War, and of the present one, on the patent situation is discussed in respect of the metal zinc; attention is also directed to the influence of patent legislation and how it affects the future.

BECAUSE of its anti-corrosion value zinc is one of the most useful metals. Although its brittleness renders it difficult to work by itself, and in this respect limits its employment to such things as gutterings, etc., as a component of alloys, and as a coating in sherardising and in galvanising, for example, the use of zinc is very general. Some 50% or so of the element finds employment in galvanising. Zinc is alloyed with aluminium, copper, nickel and tin for various purposes, e.g., foundry work and die-casting. In pigments, too, as a compound, there is a large field for zinc. Corrugated iron, door and window handles, automobile fittings, carburettors, oil-pump bodies, and many other things call for zinc in one or in other of its forms. The impetus of war output created an increased demand for articles of which zinc forms an important part.

Wherever development of an industry is in progress a corresponding demand is made upon the ingenuity of inventors. This entails an increase in the number of patents taken out.

It will be of interest, therefore, to enquire how the last war, and the present one, have affected the patent situation in respect of the metal under consideration, and how patent legislation affects the future. The thirty-year period, 1910-41, is very convenient, as the patent search into novelty was introduced in 1907.

TABLE SHOWING APPROXIMATE NUMBERS, AS ESTIMATED BY THE WRITER, OF PATENTS RELATING TO ZINC ALLOYS GRANTED DURING THE PERIOD 1910-1941.

Year.	Patents.	Year.	Patents.	Year.	Patents.	Year.	Patents.
1910	13	1918	10	1926	15	1934	37
1911	16	1919	11	1927	16	1935	35
1912	11	1920	12	1928	16	1936	28
1913	11	1921	14	1929	19	1937	40
1914	13	1922	13	1930	25	1938	38
1915	9	1923	13	1931	33	1939	48
1916	7	1924	12	1932	32	1940	41
1917	8	1925	15	1933	28	1941	45

The above data are shown in the accompanying graph. A consideration of the curve reveals the increase of the use of zinc alloys since the last war.

In industries such as those connected with the metal under discussion, patents are a very fair index of the state of the industry. After each surge upwards since 1930 there has been, it is true, a fall, but that is natural after a particularly rapid rise. Let us glance at a few recent patents in Britain, Canada and the United States.

538,637 (Schnellen and Ors). An alloy containing zinc. The alloy consists of chromium, 0 to 0.75%; copper, 1.5 to 1.85%; magnesium, 0.40 to 0.90%; tin, 1.25 to 1.75%; titanium, 0.15 to 0.20%; zinc, 0.75 to 1.75%; aluminium to percentage balance. Such an alloy is capable of use without heat-treatment.

Canadian, No. 397,808 (Hudson Bay Mining and Smelting Co.). A method of refining zinc. Impure zinc in slab or sheet form is amalgamated with mercury. The sheet or slab is made the anode in an electrolytic cell. The zinc is electrolysed by plating on to a suitable cathode.

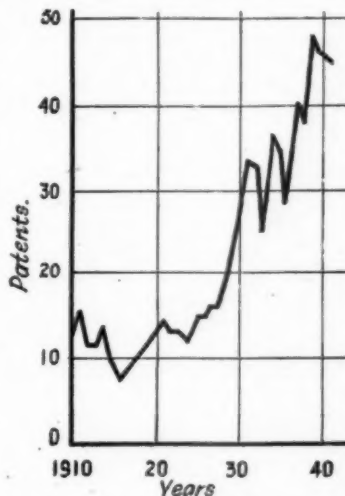
United States, No. 2,257,085 (Stolberger Zink A.-G. and Metallgesellschaft A.-G.). Batch process for liquating zinc from zinciferous material, such as zinc dust and trass containing zinc in elementary form. The charge to be liquated is introduced into a moving liquating furnace. The charge is heated not later than when the original charge has reached a plastic dough-like consistency, but when it has undergone a decrease in volume, and before much zinc has

been liquated from the original charge, a further charge of the material to be liquated is introduced into the furnace.

With the present state of invention in the metallurgical industry well before us, we are now in a position to appreciate the importance of war-patent legislation thereon. First, however, we will refresh our minds about the Patents, Etc. (Emergency) Act, 1939.

Under Sections 1 and 2 the Comptroller is enabled to revoke, vary a licence, or grant an emergency licence under a patent granted to an enemy or an enemy subject.

Although patent applications by enemies are still permitted under Section 4, they are very much restricted



under this year's Board of Trade licence. Practically all patent office work on such applications has closed down, except by special licence of the Comptroller. Renewal fees, however, can still be paid. Under Section 6 the Comptroller is enabled to extend the time for paying patent fees, filing patent documents, and so on, under certain circumstances, if delay has been due to the war.

A new Patent Act has come into force. Let us examine it in conjunction with the relevant Statutory Rules and Orders.

The 1942 Patents and Designs Act is mainly directed towards the amendment of Sections 18 (6), 29, and 91 of the previous Act.

Section 18 (6) enabled a patentee to obtain, say for a zinc alloy patent, an extension of term on the sole ground of loss or damage due to hostilities. The new Act limits such extension to ten years. Under certain conditions an extension of time for the application may be granted where in the ordinary way the patent was due to expire between February 26 and August 26, 1942.

Section 29 of the previous Act relates to the right of the Crown to use patented inventions. The new Act extends such rights. It affirms the power of a Government department, putting it shortly, to do what it likes with a patent, say for a patent for refining zinc, for purposes connected with the efficient prosecution of the war, or the maintenance of essential national supplies or services during hostilities for that purpose, and to override any existing agreement under the patent. The new Act also protects purchasers of surplus Government stock made under this section.

To Section 91 of the prior Act, which deals with what are technically known as "Convention" applications, two important subsections, B and C, are added. A "Convention" patent application is one which is filed in a country which is not that of origin, and enjoys certain priority privileges under international agreement. Such countries are known as "Convention" countries. According to Subsection 91B of the new Act, the Comptroller has power, where reciprocal privileges are granted, to extend the filing and other periods under certain conditions, and vary the patent procedure.

Subsection 91C protects a subsequent patent application from invalidation by prior communication of the subject matter of the invention between the States concerned.

Let us now turn to a somewhat earlier document of much interest. This is Statutory Rules and Orders 1780/1941 (Defence Regulations, 1941). Under Rule 3 (1) of these S.R. and O. the Comptroller may, on the advice of the Government, in the interests of the Defence of the Realm, hold up a patent application, and prohibit or restrict publication of any information relating to it. This tallies with Section 30 of the Patent Act relating to secret patents. Subsection 2 prohibits anyone making a patent application abroad except by the written permission of the Comptroller, or a person holding his authority.

By Subsection 3 the Government can, in the interests of national defence or of the prosecution of the war, direct any person having information concerning an invention or a process, e.g., for the liquation of zinc, to furnish such to a Government agent. Publication only, however, of this kind will not invalidate subsequent application for a patent, nor will that agent's handling of the invention or process so do.

Use of drawings, documents or other information in any manner necessary for the prosecution of the war, or of carrying out national defence may be authorised by the Government under Subsection 5, despite any clause to the contrary in a licence or agreement, and clauses therein relating to payment for such user, except for the benefit of the Crown, are inoperative. The Government can place its contracts where it likes, here or abroad. It expects its nationals to obtain Government approval before disposing of foreign patent rights, and also to submit to it claims for royalties, etc., abroad.

In this connection let us for a moment reconsider Section 29 of the 1907-1942 Acts, to note that exceedingly wide powers are given to Government departments to unearth anticipatory material relative to a patent. The section, of course, affirms the right of a patentee to receive remuneration from the Government for Crown use of his invention. This payment can be settled by agreement where the user is affected, or subsequently by a post-war tribunal. It will be appreciated that the royalty, etc., offered will generally be assessed in the light of the Government research into novelty, and may differ considerably from that at which the patentee had figured it.

Returning to Rule 5 (S.R. and O. 1780/41), we find that where the Comptroller has granted an Emergency Licence under the 1939 Act, a subsequent licence under the same patent is void unless it be granted by the Comptroller or with his previous approval, or unless the licensee be licensed as an acquirer of the article. Procedure is set out in S.R. and O. 73/1942. Opposition can be lodged.

Rule 6 deals with the trade-mark difficulty. Sometimes of practical necessity, a registered trade-mark is employed in a patent specification to describe the patented article. Where an emergency licence is or will be granted, and such a trade-mark is used in the specification, but is not the property of the patentee, the Comptroller may make an order relating to the trade-mark and in favour of the licensee.

Let us finish up by referring again to our old acquaintance, Section 29. Sometimes a dispute occurs as to payment between the patentee and the Government. At present it appears that this will not debar the patentee from getting a contract under his own patent, pending the settlement of the dispute; however, it will be "ex royalty."

Government contractors under this section are not allowed to pay royalty to a patentee, but must hand over all such questions to be dealt with by the Government. They must also state what patents they want to use.

Let us hope that after the war inventors and patentees will meet with reasonably generous treatment. At least they will need it.

Internal Stress of Metals

(Continued from page 117.)

By this means parts could be tested which, like gears for aero engines, have to withstand great stresses in the engine, and which, due to their shape and section, are liable to contain high-concentrated internal stresses even after stress relieving at low temperatures. The gears containing excessively high internal stress could be set aside.

The magnetic permeability method would be much more complicated, but the apparatus might possibly be based on the apparatus evolved by Reid,⁸ which consists of two exactly similar magnetising coils within which are mounted two exactly similar search coils, connected in series, opposing each other. A suitable specimen of the same metal relatively free from internal stress would be placed in one set of coils and the specimen under test in the other. A wave form of the difference in *e.m.f.* induced in the two search coils would be indicated by an oscillograph, the wave forms being indicative of difference in conditions between the specimen under test and the standard specimen. In other words, if the specimen under test and the standard specimen were of the same material, and in the same structural condition, i.e., hardened and tempered, etc., the relative amount of internal stress present in the specimen under test might be found.

The author therefore hopes that some research institution with the necessary equipment will, when there is more time for devotion to work of this character, investigate the probability of obtaining a simple non-destructive test for the measurement of internal stress in metals.

⁸ "Magnetic Inspection Achievements," L. S. Reid, *Metal Progress*, 1931, Vol. 19.

